A STUDY OF THE HALF LIFE AND DECAY ENERGIES OF RUBIDIUM 86.

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THE UNIVERSITY OF ALBERTA

"A STUDY OF THE HALF LIFE AND
DECAY SCHEMES OF RUBIDIUM 86".

A DISSERTATION
SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

FACULTY OF ARTS AND SCIENCE
DEPARTMENT OF PHYSICS

by

Albert John Goodjohn, B.Sc.

EDMONTON, ALBERTA,
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The undersigned hereby certify that they have read and recommend to the School of Graduate Studies for acceptance, a thesis entitled " A Study of the Half-Life and Decay Energies of Rubidium 86",

submitted by Albert John Goodjohn, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

Professor D. B. Scott

Professor H. B. Newbound

April, 1951. Professor [illegible]

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List of Plates and Graphs

Abstract

A study has been made of the decay energies of rubidium 86 using an aluminum absorption apparatus and a Wilson cloud chamber. The beta-ray spectrum is complex with end-point energies for the two groups of 1.80 and 0.69 mev. Measurement of the source activity over a period of 60 days showed the half-life to be 19.5 days.

Introduction

A Previous Work on Rb^{86}

The radiations from Rb^{86} have been studied by many investigators, using various methods of determining the half-life and energies of the beta rays and gamma rays emitted.

Snell (1), in 1937, found an 18-day period by the slow neutron bombardment of Rb. Helmholtz, Pecher and Stout (2) assigned this activity to Rb^{86}, and found the half life to be 19.5 days by following several samples over from one to four half-lives. They suspected the presence of a weak long-period activity in their samples, so that the half-life could be somewhat shorter. From absorption measurements they obtained a value of 1.56 mev for the upper limit of the beta-ray spectrum.

Using a beta ray spectrograph, Haggstrom (3) found an end point energy of 1.60 mev. From a Kurie plot of Fermi's theory she found the points did not lie on a straight line, (Plate 1) as was to be expected since rubidium lies on the second-forbidden Sargent curve.

Zaffarano, Kern and Mitchell (4) studied the complete disintegration scheme of Rb^{86} using a magnetic lens spectrometer. Measurement of the energies of photoelectrons produced in a lead radiator showed the presence of a gamma-ray of energy 1.081 mev. The shape of the beta-ray plot indicated a complex spectrum and an inspection of the Fermi plot (Plate 2) revealed two beta ray groups with end points of 1.866 and 0.716 mev. The low energy group was found to comprise 20 percent of the total beta-emission.

By coincidence experiments Jurney (5) verified the existence of this complex spectrum, and using aluminum absorption he showed the beta-ray groups with end points at 1.82 Mev (67 percent) and 0.56 Mev (33 percent). The maximum gamma ray energy was found to be 1.12 Mev by coincidence absorption of Compton recoil electrons produced in an aluminum target.

We have measured the energies of these radiations by two methods, from a Kurie plot using $H\rho$ values of a large number of photographed tracks in a Wilson cloud chamber, and by means of aluminum absorption using a thin window TGC-2 Geiger tube and a set of calibrated absorbers. The half life has been measured from the rate of change of activity over several half-value periods using the same tube.

B The Fermi Theory of Beta Decay

Fermi's theory of beta decay (6) was based on five fundamental assumptions in analogy to electromagnetic theory.

(1) The neutron and proton are two states of the same particle (nucleon).

(2) Energy, spin and statistics are conserved in beta radiation by the introduction of the Pauli neutrino.

(3) The rest mass of the neutrino is zero, (or nearly zero) and its spin is 1/2 $\hbar$.

(4) The neutron and proton interact with the combined fields of electrons and neutrinos in such a way that an electron and a neutrino are radiated when a neutron changes to a proton, and a positron and a neutrino are radiated when a proton changes to a neutron.

(5) The electron and neutrino share the available energy in all possible proportions.

For energy distributions Fermi's equation (7) reduces to the form

$$N(E)\,dE = E(E^2-1)^{1/2}\,(E_o - E)^2\,dE \qquad \text{.......................(1)}$$

for 'allowed' transitions,

where $N(E)\,dE$ = number of beta particles whose energy lies between E and $(E + dE)$.

$$E = \frac{\text{total energy of beta particle}}{m_o c^2}$$

$$(E^2-1)^{1/2} = \frac{\text{momentum of beta particle}}{m_o c}$$

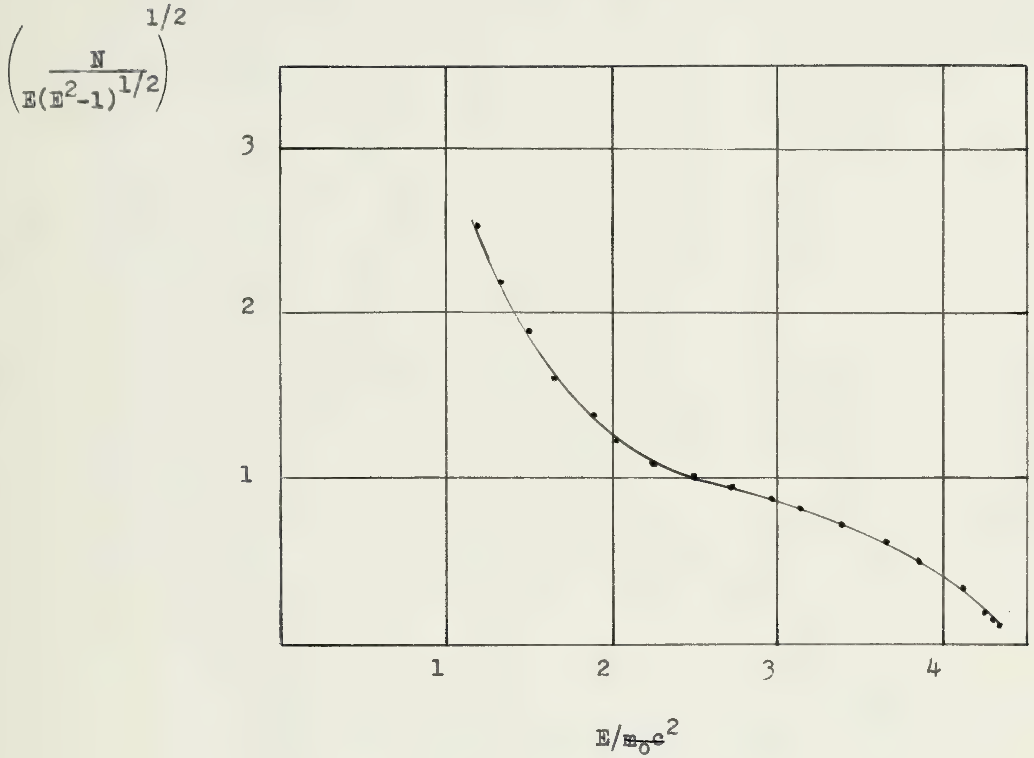
$$E_o = \frac{\text{Total energy available in disintegration}}{m_o c^2}$$

Kurie, et al (8) rearranged Fermi's equation to obtain

$$F(E) = \left(\frac{N(E)}{E(E^2-1)^{1/2}}\right)^{1/2} = E_o - E \qquad \text{........................(2)}$$

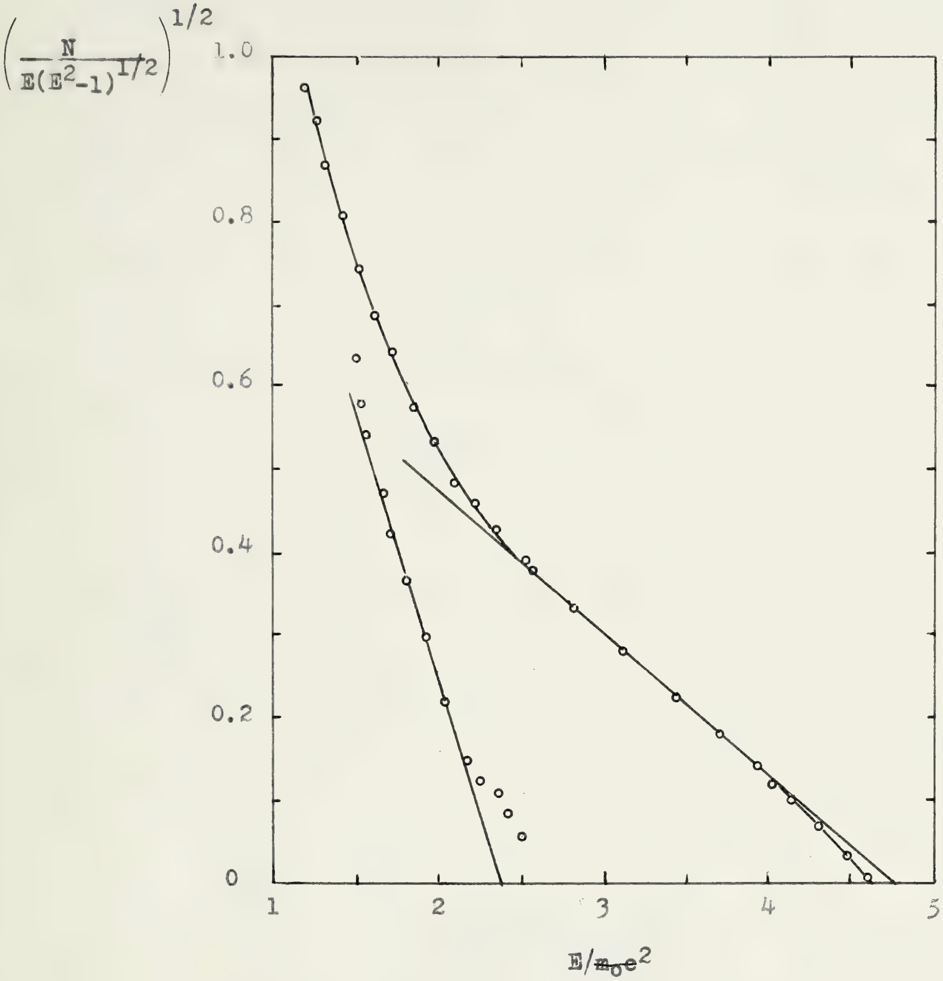
A Kurie plot of $F(E)$ against the energy E, results in a straight line cutting the E-axis at E_o, for transitions which follow the Fermi theory.

Forbidden transitions, i.e. those that result in either low energy particles or short lifetimes, presented many difficulties in the measurement of the energy spectra. The Kurie plot of data resulted in a large deviation from the straight line relationship. Konopinski and



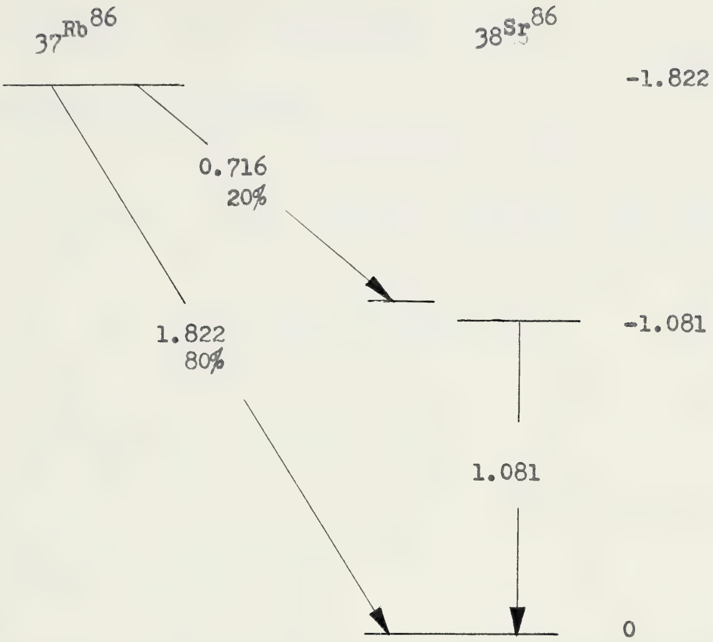
(Plate 1)

Fermi plot for rubidium 86. (E. Haggstrom)



(Plate 2)

Fermi plot of the beta ray spectrum of Rb^{86}.
(Zaffrano, et al.)



(Plate 3). Disintegration Scheme of Rb^{86}
(Zaffarano, et al.)

Uhlenbeck (9) proposed an alternative theory to explain these forbidden transitions but the theory proved inadequate. No modification has thus far been found to explain these spectra.

C Analysis of Absorption Data.

The large discrepancies existing between various published values of end point energies found by aluminum absorption, due to the cumbersome and inaccurate visual inspection method, led Katz et al (10) to develop a new method of analyzing absorption data.

Their method assumes that the lower part of the absorption curve (Plate 4) follows a power law of the form

$$y = K_1 (E_o - E)^n \quad \ldots\ldots (3)$$

where y is the fractional transmission

E_o is the endpoint energy

E is the energy of particles just absorbed at a given thickness of absorber

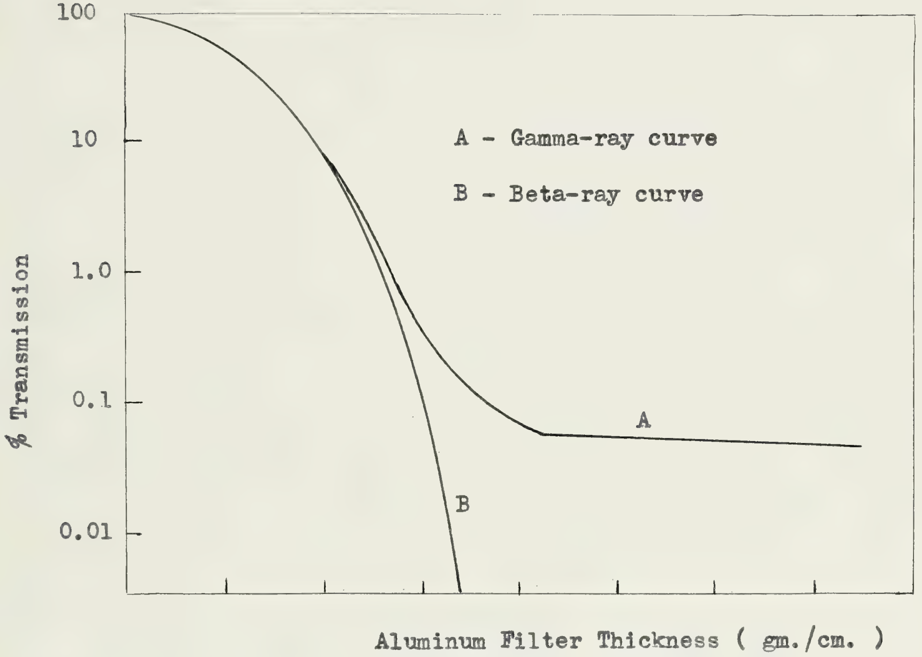
n is a positive constant greater than unity and either fractional or integral.

By rearrangement of this equation or taking the logarithms of each side, the resulting expressions are

$$y^{1/n} = K_2 (E_o - E) \quad \ldots\ldots (4)$$

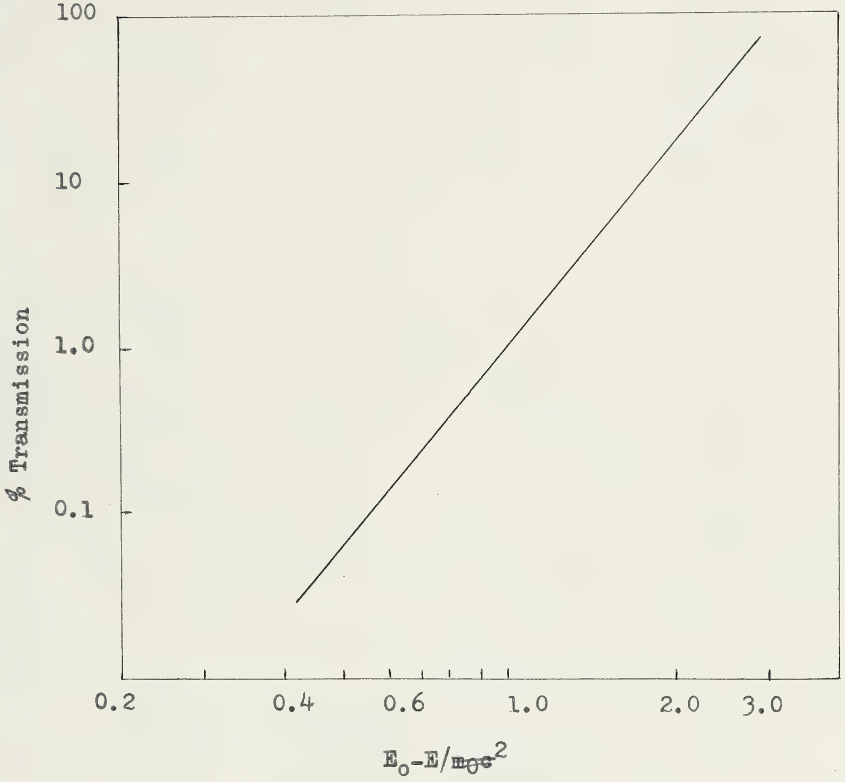
$$\log y = \log K_1 + n \log (E_o - E) \quad \ldots\ldots (5)$$

Assuming an end point E_o' from the data, a plot on log-log paper is made of y *vs* $(E_o' - E)$, and the slope is determined to give a value



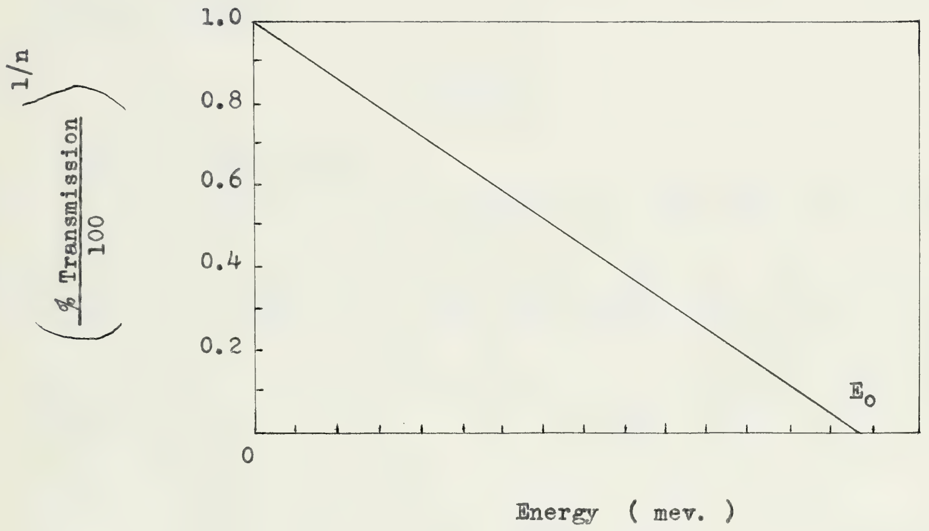
(Plate 4)

Aluminum absorption curve for beta rays.



(Plate 5)

Method of determining a value of n. The abscissas are the energies corresponding to a given filter thickness.



(Plate 6)

Plot of $y^{1/n}$ against E to obtain a value of E_o, the maximum beta energy.

of n say n' (Plate 5). Thence by plotting $y^{1/n'}$ a new value of the end point E''_0 is obtained. (Plate 6) The process is then repeated with a convergent sequence resulting from the successive approximations to E_0. If a plot is then made of $E''_0 - E'_0$ vs E'_0 obtained in each case, an extrapolation to $\Delta E = 0$ will give the best value of the end point energy. The method has proved very successful in the few examples studied (10,11).

Apparatus

A Counting Apparatus

The counting apparatus consisted of a Model 161A Atomic Instrument Company Scale of 64 Scaler with pre-amplifier and associated circuits (Plate 7). A TGC-2 Geiger Tube with a window thickness of 1.7 mg/cm^2 was enclosed in a lead castle of 1.5 inch wall thickness. Shielded leads were used throughout. A Sola constant-voltage transformer was used to provide a reasonably stable voltage supply.

The tray system within the castle consisted of a lucite box (Plate 8). A hole was machined in the upper plate into which the tube fitted snugly. Side slots were machined in the lucite to hold the trays.

The trays for the half-life measurements were cut from aluminum sheeting and shaped to fit the side slots snugly. To assure a constant geometry, the source holders were cemented to these trays.

For the absorption measurements a special tray was designed to eliminate the effects of back scattering (Plate 9). This tray was made of 3/8" lucite with side flanges cut to fit the slots provided.

A 1 3/4" wide circular well was machined in this tray to a depth of 1/8". The bottom of this well was then taken out to a width of 1 1/2". This left a 1/8" wide circular ledge upon which was placed a circular wire frame. A vinylite film, approximately 0.3 micron thick was placed across this wire frame. The source was then placed in the centre of the film. Loss of energy of electrons back-scattered from the film was considered negligible.

The aluminum absorbers used were of the type E-3A supplied by Tracerlab. Co., and varied in thickness from 1.64 mg/cm^2 to 1.64 gm/cm^2.

B Cloud Chamber

1. Cloud Chamber Proper

The cloud chamber (Plate 10) was made in the National Research Council Shops at Chalk River. It is a circular cylinder nine inches in diameter bounded by a lucite wall, a glass plate on top and a perforated brass plate on the bottom. Below the brass plate is a rubber diaphragm. The space below the diaphragm is connected by a Sylphon-bellows valve system to a vacuum tank.

2. Helmholtz Coils

The Helmholtz coils were built in the National Research Council Shops at Chalk River. The magnetic field was found to be uniform within 0.5% over a region bounded by planes 2.5 cm. above and below the horizontal plane through the midpoint of the coils and a cylinder of 9 cm. radius. (12).

3.– The Camera.

The camera was built in the University of Alberta. It is fitted with a Leica Elmar lens of 50 mm. focal length and aperture f:3.5. Thirty five millimeter film is used. An aluminum stand, bolted to the top Helmholtz coil, supports the camera, and also two front-aluminized mirrors placed vertically facing each other at the top of the cloud chamber. A single photograph consists of a direct image of the cloud chamber, and two half images, one from each mirror. In this way a complete stereoscopic view of the chamber is obtained.

4.– Illumination.

Conventional flash circuits are used with two flash lamps placed on opposite sides of the chamber.

5.– Control Circuits (Plates 11 and 12) (13)

The automatic operation is controlled by a series of timing circuits. Each circuit consists essentially of a thyratron whose grid voltage is controlled by a condenser and variable resistors. When the voltage on the grid has reached a value above cut-off the thyratron fires closing a relay in the plate circuit. This relay in turn closes the circuit of another thyratron or an external circuit which then performs one of the operations required. The time delay between the various events is adjusted by varying the resistors in the corresponding grid circuits. The order of events is established by a selector switch operated by a solenoid. The solenoid is actuated by one of the timing circuits.

6. The Cycle of Operations

Just prior to the major expansion of the chamber the Helmholtz coils are turned on. The same circuit advances the film one frame and opens the camera shutter. After a delay sufficient to allow the magnetic field to reach a steady value the major expansion takes place. After an interval of 1/50 second the lamps flash. The Helmholtz coils are then turned off, the shutter is closed, and the chamber recompresses. The complete cycle of operation consists of three minor expansions, two dead intervals and one major expansion. The cycle is repeated after 72 seconds.

7. Tilting Table (Plate 13)

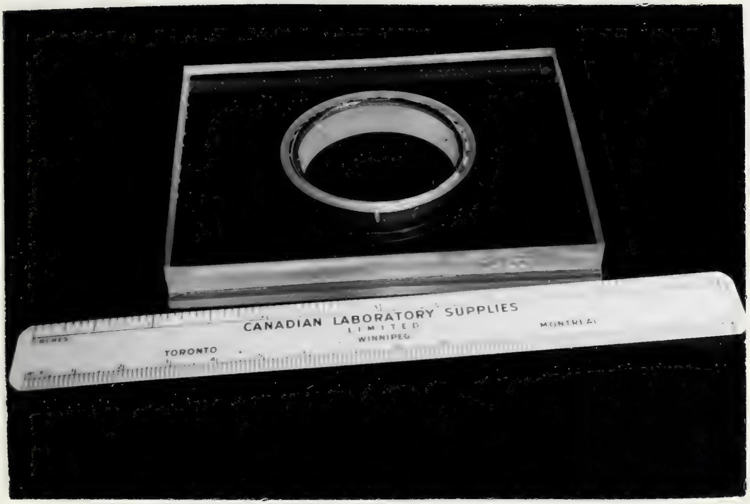
A 12" by 12" bakelite sheet, painted white, was used to view the tracks. An electromagnet is used to clamp the table at any angle up to 5^{0} to the horizontal. The chord length was measured by a ruler and the sagitta length by a micrometer screw.

(Plate 7)

Counting Apparatus.

(Plate 8)

Lead castle, TGC-2 Geiger tube,
lucite tray holder and tray.

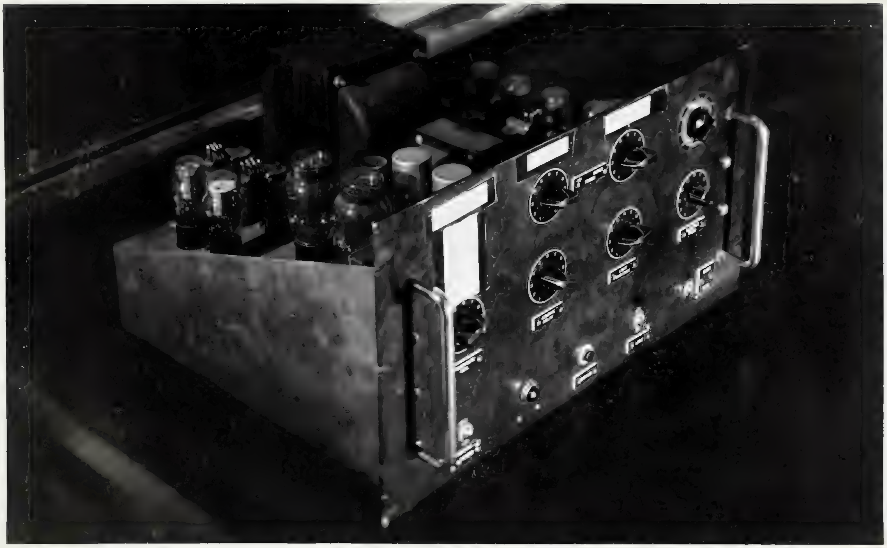


(Plate 9)

Special lucite tray to minimize backscattering.

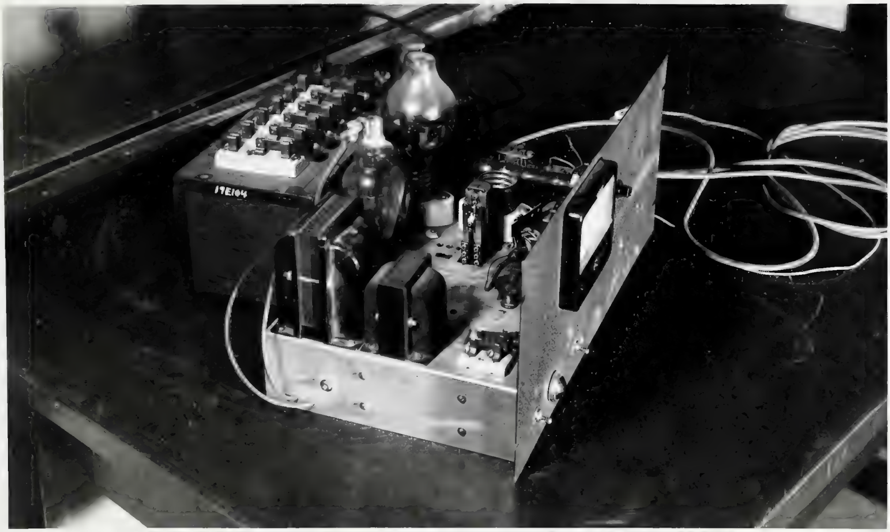
(Plate 10)

Cloud Chamber, completely assembled.



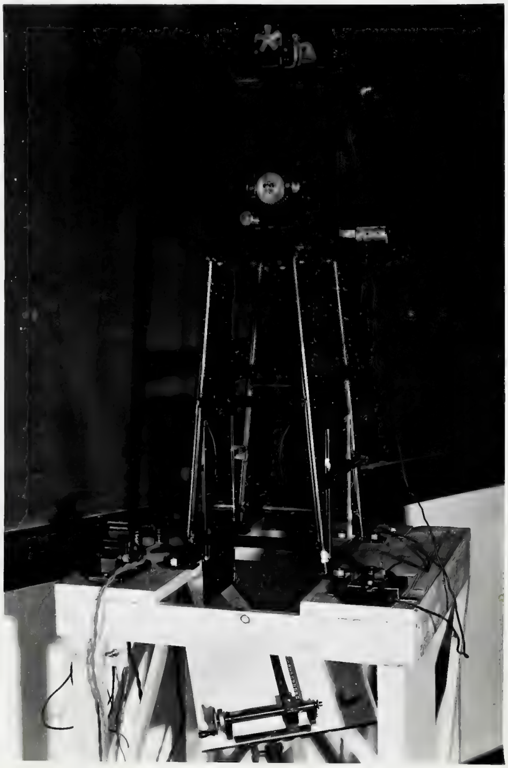
(Plate 11)

Main Control Circuit.



(Plate 12)

Automatic and flash control circuits.



(Plate 13)

Tilting Table with Camera.

Experimental Method

A Preparation of the Rb^{86} Sources

One gram of chemically pure Rb_2CO_3 was obtained from the City Chemical Corporation, New York and was dissolved in 100 ml. of distilled water. Since Rb_2CO_3 was discovered to be highly deliquescent, 0.5 ml. of this solution was placed in a hollow 1/4" quartz tube 1 1/4" long with one end sealed and the other drawn to a bore of 1/16" to assure fast sealing later. The water was evaporated off to apparent dryness. An oxy-hydrogen torch was applied to the sides of the tube to assure dryness and the drawn end was quickly sealed. This tube was then irradiated in the Chalk River pile. Since the pile temperature is 150°C, it was necessary to be sure that residual water in the tube was not capable of producing a pressure at this temperature sufficient to explode the tube. This was done by placing the tube for two hours in an oil bath at 175°C. This was found to be a safe temperature. Outside surface contaminants were removed by washing in dilute sulphuric acid after which the tube was placed in a steam bath for two hours.

The irradiation time was 24 hours at 10^{13} neutrons per cm^2 per sec. Calculations previous to shipment estimated that the activity of the rubidium would then be 0.13 mc. (Appendix 3).

The irradiated material was removed from the quartz cylinder by breaking the cylinder in 10 ml. of distilled water. The quartz chips were filtered off and the solution was placed in an Erlenmeyer flask.

An eye-dropper was used throughout to place drops of the source on the various source holders.

For use in the Cloud Chamber, source material was placed on a vinylite film stretched across a wire frame similar to that described by Hetherington (13), consisting of a U-shaped wire with a vertical copper rod support tapped to fit a specially prepared hole in the brass base plate of the chamber. The activity of the source was adjusted to give approximately seven tracks per picture. The source was evaporated to dryness over a 60 watt lamp and another vinylite film was glued over the top to prevent deliquescence. A two-fold purpose was served by this covering film; (1) contamination of the chamber was prevented and (2) loss of energy in the beta particles due to absorption in water was reduced.

For use in the absorption apparatus the source material was placed on the vinylite film described under Apparatus, to a maximum counting rate of approximately 12,000 c.p.m. on shelf 1.

To measure the half-life, two metal planchettes were used, with the original source activities set at approximately 15,000 and 11,000 c.p.m. on shelf 1.

B Resolving Time

The resolving time of the tube was measured by the method given by Lapp and Andrews (14), using two standard sources with counting rates of approximately 7000 c.p.m. and 13,000 c.p.m. on shelf 1.

C Measurement of Half-Life of Rb^{86}

The activity of two samples of Rb^{86} was followed for a period of 80 days or approximately 4 half-life periods (Graph No. 1). Measurements were taken each day and the following order was used each day throughout.

1. Five one minute readings on source No. 1
2. Five one minute readings on source No. 2
3. Five one minute readings on the standard source (Appendix 1).

D Measurement of the Decay Energies of Rb^{86}

(1) Aluminum Absorption Measurements.

The absorption readings were taken in the following manner.

1. Five one minute readings on the Rb^{86} source with no absorber.

2. Five one minute readings on another Rb^{86} source which was used as the standard.

3. Five one minute readings on the first Rb^{86} source with absorber No. 1, 1.64 mg/cm^2, between the tube and the source.

4. Five one minute readings on the standard Rb^{86} source with no absorber.

This procedure was repeated for the complete set of twenty-five absorbers (Graph No. 2).

Correction for decay and for possible variations in counting efficiency was accomplished in the following manner:

1. The first standard reading was taken as an arbitrary standard.
2. Subsequent standard readings were normalized to this value

3. The average counting rate for a given absorber was then corrected using the standard readings taken immediately after it.

Since the tube used was inefficient for gamma ray counting, and the source strength was quite low, it was found impossible to obtain accurately the gamma ray curve. The source strength was increased to approximately 40,000 c.p.m. on shelf 2. Absorber No. 11 - 660 mg/cm^2 was placed over the source and the percent transmission was established to a high degree of accuracy. The gamma ray curve was then obtained by adding a series of second absorbers. In this way the maximum filter thickness was increased to 2300 mg/cm^2. (Graph No. 2).

<u>(2) Cloud Chamber Method</u>

A hole one inch from the side wall of the chamber was tapped with a 6-32 tap. The source support was placed in this hole (Plate 14). A maximum range of 8 inches was thus available to the tracks and tracks reflected from the back wall could be discarded.

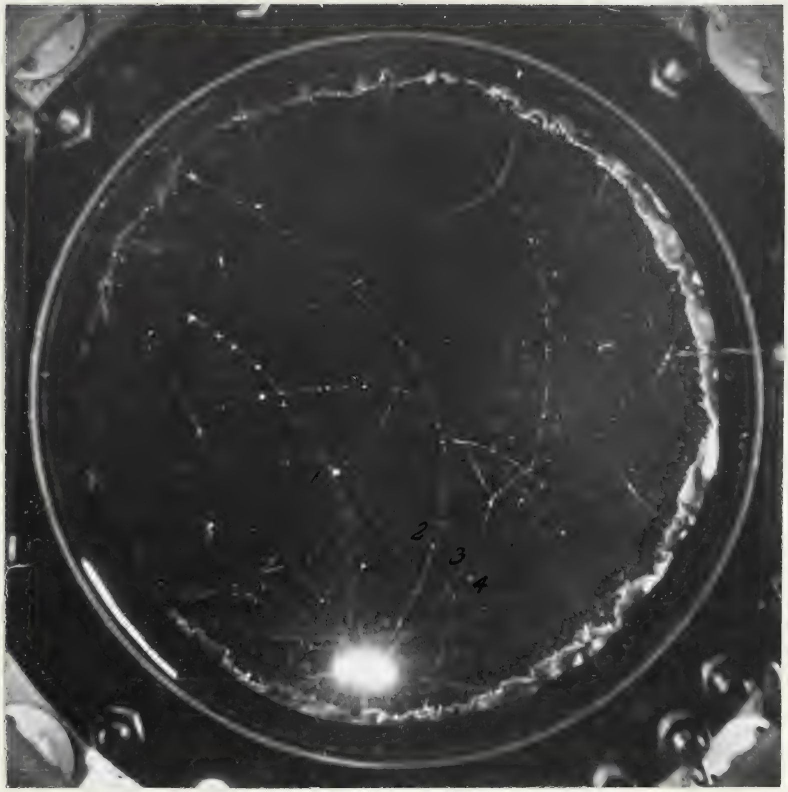
Stereoscopic photographs of the beta-particle tracks were taken in air at atmospheric pressure. The working mixture consisted of 5 cc. of a 1:2 mixture of ethyl alcohol and water by volume.

The film was tank developed for six minutes at 20 degrees centigrade using high contrast developer formula D-19 by Kodak. It was then fixed for eleven minutes using formula F-5.

(3) Method of Measurement

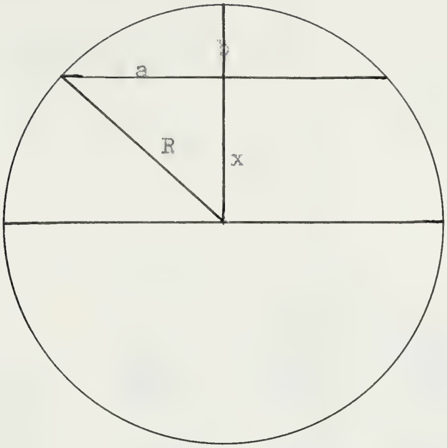
The camera and stand were removed from the chamber and placed in position on the tilting table. The lens to table distance was made the same as the lens to source distance in the chamber. The developed film was replaced in the camera in the same position that it occupied when the photographs were taken and the tracks were reprojected on the white table top by means of a 200 watt projection lamp. The source image was placed centrally on the levelled table top and the three views made to coincide as each frame was brought under the lamp. The table top was kept level at all times since the horizontal projection of the radius of curvature of each track was required. Several criteria were established which each track was required to satisfy in order to be considered acceptable for measurement. The criteria were as follows: (1) the track must be of the proper direction of curvature. (2) It must be visible to 5 cm. or more from the source (3) It must appear to have its origin in the source. (4) It must suffer no detectable deflections from a circular path in 5 cm. In addition to the above criteria tracks which showed noticeable diffusion of the ions were excluded. The radius of curvature of each track was calculated from measurements of a chord length and the segment length connected with that chord (Plate 15). The tracks in each frame were numbered starting at the left-hand side of the source and going in a

clockwise direction. Hρ limits were calculated for equal energy intervals of 100 kev. and the tracks were classified into these groups. A number vs energy histogram was plotted (Graph 5) and Fermi's theory was applied to this histogram.



(Plate 14)

Method of numbering tracks. Note position of source.



$$x^2 + a^2 = R^2$$

$$x + b = R$$

Solving for R,

$$(R - b)^2 + a^2 = R^2$$

$$R = 1/2 \left(\frac{a^2}{b} + b \right)$$

(Plate 15)

Method of calculating the radius of curvature.

Observations

Measurement of Half-Life of Rb^{86}

Dead-time of Tube - - - - - - - - - - - - - - - 4.51×10^{-6} minutes

Tube Voltage - 1280 volts

Discriminator Setting - - - - - - - - - - - - - - 5 (negative side)

Background - 32 cpm

		Average 5 - 1 minute counts			cpm corrected for dead time, background and standardized	
Date	Time	Source No. 1	Source No. 2	Standard No. 5	Source No. 1	Source No. 2
Dec. 7	9 A.M.	14051	10766	11657	14679	11071
Dec. 8	9 A.M.	13589	10273	11515	14345	10676
Dec. 9	9 A.M.	13062	9816	11342	13157	10345
Dec. 11	9 A.M.	12286	9390	11523	12882	9711
Dec. 12	9 A.M.	11864	9400	11419*	12534	9816
Dec. 13	9 A.M.	11541	8577	11411	12183	8927
Dec. 14	9 A.M.	10859	8184	11194	11660	8678
Dec. 15	9 A.M.	10418	7858	11144	11218	8359
Dec. 16	9 A.M.	10040	7641	11092	10843	8161
Dec. 18	9 A.M.	9391	7068	11042	10160	7563
Dec. 20	3 P.M.	8706	6649	11193	9256	7001
Dec. 22	3 P.M.	8296	6268	11434	8608	6442
Dec. 22	3 P.M.	8171	6143	11264	8604	6410
Dec. 24	3 P.M.	7421	5628	11010	7978	6000
Dec. 26	3 P.M.	6900	5213	10779	7562	5563
Dec. 27	3 P.M.	6751	5022	11069	7194	5309
Dec. 28	3 P.M.	6543	4955	11241	6856	5153
Dec. 29	3 P.M.	6345	4820	11134	6716	5065
Dec. 30	3 P.M.	5947	4550	10787	6489	4933
Dec. 31	12 Noon	5816	4409	11008	6206	4675
Jan. 2	9 A.M.	5585	4249	11144	5879	4445
Jan. 3	9 A.M.	5360	3995	11025	5697	4221
Jan. 4	9 A.M.	5137	3814	11014	5462	4030
Jan. 5	9 A.M.	4923	3729	10916	5283	3979
Jan. 6	9 A.M.	4819	3580	11008	5120	3783

* This value was chosen as the arbitrary standard.

Date	Time	Average 5 - 1 minute counts Source No. 1	Source No. 2	Standard No. 5	cpm corrected for dead time, background and standardized Source No. 1	Source No. 2
Jan. 7	12 Noon	4678	3538	11227	4864	3660
Jan. 8	9 A.M.	4425	3338	10921	4732	3552
Jan. 9	9 A.M.	4385	3250	11156	4585	3380
Jan. 10	9 A.M.	4223	3187	11210	4388	3298
Jan. 11	9 A.M.	4095	3079	11300	4218	3158
Jan. 12	3 P.M.	3905	2905	11210	4053	3002
Jan. 13	9 A.M.	3833	2853	11273	3954	2929
Jan. 14	3 P.M.	3625	2686	10996	3835	2829
Jan. 15	9 A.M.	3530	2675	11171	3672	2771
Jan. 16	9 A.M.	3450	2553	11272	3553	2619
Jan. 17	9 A.M.	3293	2431	11118	3439	2529
Jan. 18	3 A.M.	3162	2351	10916	3385	2492
Jan. 19	9 A.M.	2993	2234	11072	3133	2331
Jan. 20	9 A.M.	2893	2166	10934	3068	2290
Jan. 22	9 A.M.	2627	2058	10885	2796	2165
Jan. 23	9 A.M.	2609	1956	10896	2774	2073
Jan. 24	9 A.M.	2511	1881	10844	2681	2003
Jan. 25	9 A.M.	2405	1790	10908	2551	1884
Jan. 27	9 A.M.	2270	1675	10975	2391	1759
Jan. 28	3 P.M.	2146	1582	10836	2290	1685
Jan. 29	3 P.M.	2121	1567	10856	2258	1664
Jan. 30	9 A.M.	2024	1525	10837	2158	1622
Feb. 1	9 A.M.	1914	1387	10986	2028	1467
Feb. 2	3 P.M.	1859	1370	11080	1936	1423
Feb. 3	9 A.M.	1780	1320	10987	1885	1395
Feb. 5	3 P.M.	1667	1223	10836	1775	1300
Feb. 6	9 A.M.	1606	1218	10850	1706	1293
Feb. 7	9 A.M.	1537	1126	10791	1642	1202
Feb. 8	9 A.M.	1500	1100	10784	1604	1174
Feb. 9	3 P.M.	1444	1100	10889	1528	1164
Feb. 10	9 A.M.	1419	1021	11391	1509	1083
Feb. 12	9 A.M.	1314	991	10817	1400	1053
Feb. 13	9 A.M.	1264	930	11413	1342	986
Feb. 15	9 A.M.	1176	884	10917	1239	
Feb. 16	9 A.M.	1184	860	10863	1255	
Feb. 19	12 Noon	1004	757	10905	1059	
Feb. 20	9 A.M.	989	725	11427	1046	
Feb. 21	9 A.M.	978	718	11325	1044	

Measurement of Decay Energies by Aluminum Absorption

Dead Time of Tube - - - - - - - - - - - - - - - 4.51 x 10^{-6} min

Tube Voltage - 1280 volts

Discriminator Setting - - - - - - - - - - - - 5 (negative side)

Background - 32 cpm

Absorber Thickness mg/cm^2	Average 5 - 1 minute counts Source	Standard	cpm corrected for dead time Source	Standard	cpm normalized and corrected for background Source	% Transmission
0.00	11977	12907	12660	13705	12628	100
5.17	11943	12873	12622	13666	12626	100
10.1	11819	12853	12484	13644	12508	99.0
21.7	11398	12864	12016	13657	12026	95.2
27.4	11153	12782	11744	13563	11835	93.7
38.6	10847	12809	11405	13594	11466	90.8
77.7	9170	12846	9565	13636	9501	75.9
87.3	8643	12668	8993	13436	9141	72.4
131	7122	12762	7358	13542	7415	58.7
170	5666	12673	5815	13441	5897	46.7
214	4413	12643	4502	13407	4570	36.2
276	2887	12582	2925	13338	2973	23.5
359	1569	12607	1580	13367	1588	12.6
445	687	12655	690	13421	673	5.3
573	215	12649	217	13415	190	1.5
	Average 12 - 1 minute counts					
0.0	36992		48303		47271	
660	258.5		260		228	0.472
	Average 10 - 1 minute counts					
660	504		507		475	0.472
699	381		382		350	0.348
738	291		292		260	0.258
791	245		246		214	0.213
830	224		225		193	0.192
874	221		222		190	0.189
936	218		219		187	0.186
1019	215		216		184	0.183
1105	214		215		183	0.181
1233	208		209		177	0.175
1443	206		207		175	0.174
1629	204		205		173	0.172
1860	202		203		171	0.170
2300	197		198		166	0.165

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	$H\rho$ gauss cm.	Total No.
(Roll No. 1)							
1	1	3.80	0.336	5.54	200	1108	3
	2	8.60	0.899	10.7		2140	
2							
3	3	4.46	0.281	8.99		1798	3
	2	5.08	0.359	9.17		1834	
	1	2.96	0.276	4.11		822	
4	1	7.85	0.692	12.0		2400	3
	3	3.86	0.328	5.84		1168	
5	3	7.84	0.522	15.0		3000	3
6							
7							
8							
9	2	7.16	0.369	17.6		3520	3
	3	5.43	0.335	11.2		2240	
10							
11							
12							
13	3	4.80	0.160	18.1		3620	4
	4	4.10	0.297	7.22		1444	
14	3	7.05	0.408	15.4		3080	4
	2	3.42	0.190	7.74		1548	
	4	6.48	0.204	25.8		5160	
15							
16	1	4.33	0.263	9.04		1808	3
17	4	5.40	0.389	9.56		1912	4
	2	6.42	0.224	23.1		4620	
18	1	7.09	0.265	23.8		4760	3
	2	6.58	0.282	19.3		3860	
	3	3.80	0.191	9.55		1910	
19	1	6.70	0.278	20.3		4060	4
	3	6.85	0.238	24.8		4960	
20	1	6.04	0.310	14.9		2980	5
	2	5.75	0.354	12.4		2480	
	4	6.70	0.211	26.7		5340	
	5	7.76	0.345	22.0		4400	
21	1	5.88	0.657	6.91		1382	3
	2	3.50	0.182	8.51		1702	
22	1	4.47	0.195	12.9	200	2580	10
	2	5.74	0.198	20.9		4180	
	5	3.58	0.425	3.98		796	
	6	2.74	0.265	3.67		734	
	9	6.66	0.501	11.3		2260	
	10	6.00	0.341	13.9		2780	

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	Hρ gauss cm.	Total No.
23	3	4.12	0.097	21.9		4380	6
	5	6.06	0.297	15.6		3120	
	6	6.97	0.260	24.0		4800	
24	1	5.08	0.317	10.3		2060	6
	3	5.98	0.427	10.7		2140	
	4	4.44	0.226	11.1		2220	
	5	3.70	0.194	8.92		1784	
25	1	5.20	0.186	18.7		3740	2
26							
27	1	6.12	0.535	9.02		1804	3
	2	3.25	0.153	8.70		1740	
28	1	6.70	0.324	17.5		3500	3
	3	3.75	0.294	6.13		1226	
29	1	4.44	0.244	10.2		2040	3
	2	5.32	0.380	9.50		1900	
30	2	6.45	0.345	15.2		3040	3
	1	3.66	0.192	8.82		1764	
31	3	5.44	0.442	8.09		1618	3
32	1	5.34	0.320	11.3		2260	4
	3	4.45	0.261	9.12		1824	
33	2	5.66	0.485	8.25		1650	2
34	1	7.65	0.302	24.4		4880	7
	4	6.04	0.400	11.6		2320	
	5	7.95	0.238	33.3		6660	
	7	6.08	0.251	18.5		3700	
35	1	6.34	0.278	18.2		3640	5
	3	6.55	0.369	14.7		2940	
	4	6.62	0.213	25.8		5160	
	5	7.24	0.225	29.2		5840	
36	2	7.50	0.311	22.8		4560	3
37	6	6.25	0.276	17.8		3560	6
	4	6.85	0.411	14.5		2900	
(Roll No. 2)							
1							
2	1	5.05	0.337	9.63		1926	3
	2	6.34	0.285	17.8		3560	
3	5	3.65	0.195	8.64		1728	5
4	1	2.44	0.404	18.6		3720	5
	2	4.66	0.404	6.92		1384	
	3	5.45	0.337	11.2		2240	
	5	5.93	0.308	14.4		2880	
5							
6	3	6.58	0.246	22.1		4420	3

Frame No.	Track No.	Chord Length Cm.	Sagitta cm.	ρ cm.	H gauss	Hρ gauss cm.	Total No.
7					200		
8	3	4.35	0.397	6.16		1232	4
	4	5.64	0.328	12.3		2460	
9	1	5.70	0.237	17.3		3460	3
10	1	3.75	0.384	4.53		906	3
	2	3.75	0.154	11.0		2200	
11	2	4.90	0.214	14.1		2820	4
	4	5.48	0.267	14.2		2840	
12	1	5.05	0.209	15.4		3080	6
	3	3.18	0.250	5.18		1036	
	4	3.50	0.266	5.89		1178	
	6	4.78	0.300	9.67		1934	
13	1	4.62	0.338	8.06		1612	3
	3	4.97	0.241	12.9		2580	
14	3	4.10	0.265	8.06		1612	3
15							
16	1	6.10	0.257	18.2		3640	5
	5	4.57	0.182	14.2		2840	
17	1	5.56	0.410	9.63		1926	3
	2	6.54	0.221	24.3		4860	
18	2	5.66	0.180	22.3		4460	4
	3	3.90	0.184	10.4		2080	
19	4	6.00	0.290	15.7		3140	5
	5	5.74	0.305	13.7		2740	
20	4	5.58	0.292	13.5		2700	4
21							
22	1	2.48	0.139	6.10		1220	5
	5	4.35	0.103	22.3		4460	
23	1	3.38	0.200	7.24		1448	3
	3	6.95	0.165	36.7		7340	
24							
25	3	5.90	0.257	17.1		3420	5
	4	4.40	0.259	9.59		1918	
	5	3.28	0.237	5.79		1158	
26	4	3.67	0.061	27.6		5520	4
27	2	3.74	0.215	8.24		1648	9
	4	2.48	0.356	21.8		4360	
	5	4.18	0.244	9.07		1814	
	6	7.43	0.305	22.8		4560	
	9	7.95	0.260	30.5		6100	
28	5	5.04	0.206	15.0		3000	5
29	2	3.10	0.151	8.03		1606	4
	3	5.55	0.173	22.3		4460	
	4	3.66	0.225	7.55		1510	
30							
31	2	4.33	0.139	16.9		3380	2
32							
33							

Frame No.	Track No.	Chord Length Cm.	Sagitta Cm.	ρ cm.	H gauss	Hρ gauss cm.	Total No.
(Roll No. 3)							
1	2	4.34	0.196	12.1	200	2420	2
2	1	2.80	0.125	7.90		1580	5
	2	4.85	0.264	13.8		2760	
	3	2.86	0.143	7.22		1444	
	5	5.34	0.171	20.9		4180	
3	3	2.94	0.259	4.30		860	3
4							
5							
6	1	5.00	0.144	21.8		4360	3
	2	3.05	0.190	6.22		1244	
	3	4.45	0.307	8.22		1644	
7	2	4.40	0.183	13.3		2660	3
	3	5.23	0.182	18.9		3780	
8							
9	2	5.72	0.342	11.6		2320	2
10	1	5.28	0.161	21.7		4340	2
11							
12	3	7.60	0.227	31.9		6380	3
13	2	6.94	0.330	18.4		3680	3
14	1	3.90	0.192	10.0		2000	6
	3	4.46	0.133	18.8		3760	
	4	4.94	0.202	15.2		3040	
	6	5.24	0.272	12.8		2560	
15	1	6.30	0.180	27.7		5540	4
	2	430	0.142	16.3		3260	
	3	4.82	0.209	14.0		2800	
16							
17	3	4.16	0.266	8.26		1652	4
	4	6.28	0.326	15.3		3060	
18	1	3.25	0.148	9.00		1800	2
19	1	4.86	0.276	10.8		2160	4
	2	3.90	0.152	12.6		2520	
	3	5.15	0.301	11.2		2240	
20							
21	1	5.36	0.185	19.5		3900	3
	3	5.30	0.145	24.3		4860	
22	3	3.32	0.285	4.98		996	3
23	1	6.28	0.206	23.5		4700	2
24							
25	2	4.36	0.191	12.5		2500	4
	3	4.60	0.148	17.9		3580	
	4	4.64	0.165	16.4		3280	

Frame No.	Track No.	Chord Length Cm.	Sagitta cm.	ρ cm.	H gauss	Hρ gauss cm.	Total No.
26							
27							
28	1	4.98	0.274	11.5	200	2300	3
	2	3.46	0.225	6.76		1352	
29							
30							
31	1	5.28	0.251	14.0		2800	4
	4	4.06	0.098	21.1		4220	
32	3	4.74	0.281	10.1		2020	3
33							
34	3	5.25	0.250	13.9		2780	4
	4	4.24	0.290	7.89		1578	
35	1	4.90	0.252	12.0		2400	2
	2	5.16	0.173	19.3		3860	
37							
38	4	5.14	0.215	15.5		3100	4
39							
40	2	2.14	0.201	3.00		600	3
	3	5.22	0.189	18.1		3620	3
(Roll No. 4)							
1	3	5.72	0.240	14.9		2980	5
	5	3.86	0.209	9.02		1804	
2	1	5.34	0.246	14.6		2920	3
3							3
4	1	5.44	0.102	36.3		7260	4
	2	5.70	0.107	38.0		7600	
5	1	2.98	0.186	6.06		1212	5
	2	3.74	0.127	13.8		2760	
	3	7.04	0.144	43.1			
	4	5.00	0.146	21.5		4300	
6							4
7	1	4.16	0.211	10.4		2080	3
8							
9	3	6.14	0.137	34.5		6900	5
	4	4.94	0.306	10.1		2020	
10	1	4.13	0.212	10.2		2040	5
	3	5.30	0.118	29.9		5980	
	4	4.04	0.200	10.3		2060	
11	3	4.36	0.110	21.7		4340	
	4	5.16	0.277	12.2		2440	
12	1	4.48	0.246	10.3		2060	2
	2	4.84	0.290	10.2		2040	
13							3
14							3
15							4

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	Hρ gauss cm.	Total No.
16	1	4.80	0.118	24.5	200	4900	
	2	3.04	0.141	8.26		1652	
	3	4.96	0.230	13.5		2700	
	4	6.84	0.260	22.6		4520	
	5	5.36	0.278	13.2		2640	
	6	4.46	0.245	10.3		2060	
17							4
18	3	5.16	0.209	15.5		3100	6
	4	4.16	0.267	8.43		1686	
19							2
20	1	3.58	0.198	8.64		1728	5
	2	4.54	0.190	13.7		2740	
	5	4.12	0.305	7.11		1422	
21							
22	1	4.88	0.191	15.8		3160	2
	2	5.50	0.287	13.3		2660	
23	1	5.72	0.240	16.6		3320	3
24							2
25	4	4.08	0.287	7.39		1478	4
26							4
27							5
	5	5.76	0.208	19.5		3900	
28	3	6.40	0.245	21.0		4200	5
	5	5.42	0.179	20.6		4120	
29							4
30	1	4.48	0.129	19.5		3900	1
31	3	5.40	0.133	27.5		5500	6
	4	3.36	0.232	6.20		1240	
	5	4.14	0.266	8.19		1638	
	6	6.70	0.174	32.3		6460	
32	1	3.22	0.274	4.87		974	5
	3	2.94	0.179	6.13		1226	
	4	6.42	0.255	20.3		4060	
	5	6.82	0.148	39.4		7840	
33							4
34	1	4.14	0.208	10.4		2080	4
	3	4.58	0.220	12.0		2400	
35							2
36	2	5.70	0.238	17.2		3440	3
	3	4.24	0.242	9.41		1882	
37							3

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	Hρ gauss cm.	Total No.
(Roll No. 5)							
1	1	4.86	0.178	16.7	250	4175	6
	5	4.44	0.115	21.5		5375	
	6	4.64	0.211	12.9		3225	
2	3	4.06	0.161	12.9		3229	4
	1	4.20	0.116	19.2		4800	
3	1	3.88	0.158	12.0		3000	7
	2	2.76	0.214	4.56		1140	
	4	3.96	0.200	9.90		2475	
	5	3.82	0.129	14.2		3550	
	6	2.28	0.211	3.19		798	
	7	5.72	0.256	16.1		4025	
4							4
5							5
6	1	3.16	0.263	4.88		1220	1
7							4
8							2
9	3	3.74	0.096	18.4		4600	4
10	3	4.10	0.190	11.2		2800	6
	4	4.40	0.119	20.4		5100	
	5	4.02	0.126	16.1		4025	
	6	3.38	0.274	5.35		1338	
11	1	5.06	0.202	15.9		3975	2
	2	3.80	0.200	9.13		2283	
12							3
13	3	3.02	0.253	4.63		1158	4
14							0
15							2
16							3
	2	4.26	0.190	10.0		2500	
17	1	3.88	0.164	11.6		2900	6
	3	4.48	0.171	14.8		3700	
	4	3.48	0.236	6.53		1633	
	5	3.52	0.205	7.66		1915	
18	3	3.22	0.231	5.73		1433	4
	4	5.34	0.263	13.7		3425	
19							2
20							2
21	1	3.54	0.147	10.7		2675	4
22	1	4.40	0.188	13.0		3250	2
23	2	6.00	0.215	21.0		5250	5

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	Hρ gauss cm.	Total No.
	3	4.56	0.179	14.6	250	3650	
	4	3.92	0.183	10.6		2650	
	5	4.00	0.246	8.25		2063	
24	2	4.08	0.166	12.6		3150	3
25							3
26	2	3.26	0.264	5.16		1290	3
	3	4.54	0.220	11.8		2950	
27							2
28	2	4.80	0.202	14.4		3600	4
	3	4.64	0.213	12.7		3175	
	4	4.64	0.234	11.6		2900	
29	2	4.40	0.174	14.0		3500	4
	4	3.26	0.210	6.43		1608	
30							0
31	1	2.98	0.182	6.19		1548	2
32	1	3.76	0.264	6.83		1708	2
	2	2.96	0.287	3.96		990	
33	2	4.26	0.196	11.7		2925	3
	3	3.16	0.192	6.60		1650	
34							3
35	1	5.26	0.237	14.7		3675	3
36							
(Roll No. 6)							
1	1	3.94	0.220	8.93		2233	4
	2	3.04	0.200	5.88		1470	
	3	3.25	0.292	4.69		1173	
	4	6.32	0.205	24.5		6125	~~1~~
2	1	3.30	0.228	5.59		1398	1
3	3	3.68	0.248	6.95		1738	3
	2	3.98	0.177	11.3		2825	
4	2	4.80	0.224	13.0		3250	5
	3	2.00	0.226	2.33		583	
5							0
6	1	4.34	0.246	9.69		2423	2
7							2
8	2	4.84	0.262	11.3		2825	4
	3	2.53	0.201	4.08		1020	
9							2
10	2	3.50	0.193	8.03		2008	2

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	$H\rho$ gauss cm.	Total No.
	1	3.84	0.239	7.83	250	1958	
11	3	5.16	0.297	11.4		2850	5
12	1	4.78	0.296	9.80		2450	4
13	2	4.12	0.215	10.0		2500	3
	3	5.10	0.231	14.2		3550	
14	1	4.04	0.170	12.2		3050	4
15	2	4.68	0.193	14.3		3575	3
	3	6.80	0.198	29.3		7325	
16							3
17	2	5.02	0.278	11.5		2875	2
18	2	4.25	0.227	10.1		2525	3
19	1	3.65	0.226	7.48		1870	3
20							2
21							3
22	2	4.08	0.233	8.55		2138	5
	3	4.46	0.249	10.1		2525	
	5	2.18	0.335	1.94		485	
23	1	4.32	0.231	10.2		2550	3
	3	2.94	0.318	3.56		890	
24	3	6.10	0.210	22.3		5575	3
25							3
26	1	4.20	0.214	10.4		2600	3
	3	4.04	0.186	11.1		2775	
	2	2.62	0.182	4.81		1203	
27	4	4.60	0.146	18.2		4550	4
28	1	5.40	0.191	19.7		4925	3
29	1	5.08	0.168	19.3		4825	3
30							2
(Roll No. 7)							
1	1	3.85	0.285	6.64		1660	1
2							1
3	1	4.46	0.232	10.8		2700	3
	3	4.98	0.310	10.2		2550	
4							1
5							3
6	1	4.20	0.238	9.38		2345	5
	3	4.30	0.250	9.37		2343	
7	1	3.08	0.185	6.50		1625	2
8	1	5.32	0.226	16.8		4200	1
9	1	3.90	0.309	6.31		1578	3
10	2	4.30	0.222	10.5		2625	5
11	1	3.30	0.352	4.04		1010	1
12	2	3.38	0.178	8.11		2028	2
13	1	4.92	0.234	13.1		3275	3

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	Hρ gauss cm.	Total No.
	2	6.54	0.242	22.2	250	5550	
	3	4.55	0.267	9.83		2458	
14	2	4.83	0.181	16.3		4075	6
	5	3.22	0.232	5.70		1425	
	6	4.42	0.245	10.1		2525	
15	1	4.70	0.272	10.5		2625	3
	2	4.30	0.180	12.9		3225	
	3	3.58	0.213	5.32		1330	
16							3
17	1	3.45	0.289	5.29		1323	3
	2	3.70	0.219	7.92		1980	
	3	4.00	0.301	6.80		1700	
18							1
19	1	4.95	0.229	13.5		3375	4
	4	4.88	0.398	7.68		1920	
20							0
21	1	5.76	0.252	16.6		4150	3
22	2	5.06	0.242	13.3		3325	3
23	1	5.75	0.204	20.4		5100	3
24	4	6.06	0.226	20.4		5100	4
25	5	3.52	0.266	5.96		1490	5
26	1	3.90	0.165	9.90		2475	2
27	4	2.90	0.253	4.28		1070	4
	3	3.61	0.134	12.2		3050	
	2	4.36	0.224	10.7		2675	
28	1	4.95	0.222	13.9		3475	3
	2	4.56	0.147	17.8		4450	
29							0
30	1	3.30	0.140	9.79		2498	5
	2	3.34	0.231	6.15		1538	
	3	5.02	0.159	19.9		4975	
	5	6.54	0.231	23.3		5825	
31	1	4.86	0.190	14.8		3700	1
32	1	3.36	0.237	6.07		1518	1
33							1
34	1	4.10	0.257	8.31		2078	2
35							1
36							2
37	1	3.80	0.200	9.15		2288	3
38							0
39	1	6.14	0.330	14.4		3600	2
	2	6.52	0.205	26.0		6500	

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H, gauss	$H\rho$ gauss cm.	Total No.
(Roll No. 8)							
1	2	4.52	0.307	8.47	250	2118	4
	3	5.00	0.184	17.1		4275	
	4	3.50	0.467	3.51		878	
2	2	5.74	0.214	19.4		4850	3
3	3	4.24	0.207	11.0		2750	3
4	3	3.92	0.145	13.3		3325	4
	4	3.68	0.220	7.80		1950	
5							4
6	2	4.30	0.229	10.2		2550	4
	4	3.54	0.283	5.68		1420	
7	1	3.46	0.217	7.01		1753	1
8	1	3.10	0.182	6.69		1748	4
	2	3.84	0.233	8.03		2008	
9	2	5.40	0.236	15.6		3900	3
	1	4.58	0.159	16.6		4150	3
10	3	4.30	0.151	15.4		3850	3
11	2	5.06	0.253	12.8		3200	4
	3	2.88	0.195	5.41		1353	
	4	4.00	0.217	9.33		2333	
12							3
13	2	4.60	0.178	14.9		3725	3
	3	3.48	0.174	8.79		2198	
14	3	4.76	0.257	11.1		2775	5
	4	3.20	0.228	5.73		1433	
	5	3.90	0.168	11.4		2850	
15	1	3.96	0.206	9.62		2405	1
16							0
17	1	5.02	0.187	16.9		4225	4
18							2
19	1	4.52	0.176	14.6		3650	4
20	3	3.60	0.184	8.90		2225	5
	4	3.95	0.229	8.63		2158	
	5	3.36	0.225	6.38		1595	
21	2	2.92	0.187	5.79		1448	4
22	2	4.06	0.208	10.0		2500	2
23	2	4.04	0.166	12.4		3100	4
	3	2.84	0.268	3.90		975	
	4	4.16	0.204	10.7		2675	

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H. gauss	$H\rho$ gauss cm.	Total No.
26	2	4.86	0.242	6.42	250	1605	2
27	2	4.40	0.252	9.73		2433	3
	3	2.86	0.180	5.53		1383	
28							3
29							1
30							2
31	1	3.56	0.195	8.22		2055	1
32	1	3.82	0.271	6.87		1718	1
33	1	5.14	0.238	14.0		3500	3
	2	4.82	0.368	8.07		2018	
	3	6.28	0.214	23.1		5775	
34	1	5.86	0.258	16.8		4200	2
	2	3.54	0.248	6.44		1610	
35							2
36							2
37	1	4.00	0.241	8.42		2105	5
	2	4.06	0.294	7.16		1840	
	3	4.14	0.161	13.4		3350	
	4	3.90	0.152	12.6		3150	
38							0
39							3
40	2	1.88	0.225	2.08		520	5
	3	4.92	0.218	14.0		3500	
	4	2.38	0.175	4.13		1033	
	5	4.80	0.198	14.6		3650	
(Roll No. 9)							
1	1	5.18	0.219	15.4		3850	5
	2	4.54	0.243	10.7		2675	
	3	4.04	0.278	7.48		1870	
	4	5.96	0.184	24.2		6050	
2	1	3.90	0.198	9.70		2425	3
	2	4.54	0.267	9.78		2445	
	3	5.42	0.211	17.5		4375	
3	4	3.58	0.213	7.63		1907	5
	5	4.52	0.204	12.6		3150	
4	2	4.10	0.196	10.8		2700	3
	3	4.20	0.174	12.8		3200	
5	1	3.96	0.266	7.50		1875	3
6	2	2.76	0.284	3.49		873	4
	3	3.90	0.203	9.47		2368	
	4	2.10	0.290	2.05		513	

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H, gauss	$H\rho$ gauss cm.	Total No.
7	1	4.32	0.351	6.82	250	1705	4
	2	3.76	0.200	8.94		2235	
	4	4.46	0.240	10.5		2625	
8							1
9							2
10	1	4.64	0.221	12.3		3075	4
	2	4.32	0.082	28.5		7125	
	3	4.55	0.209	12.5		3125	
11	3	5.40	0.270	13.6		3400	4
12	6	4.70	0.187	14.9		3725	7
	5	4.94	0.209	14.7		3675	
	4	4.64	0.213	12.7		3175	
	3	2.90	0.208	5.16		1290	
	1	3.06	0.111	10.6		2650	
13	2	3.14	0.193	6.48		1620	3
14	2	4.50	0.183	20.8		5200	3
	3	3.14	0.206	6.09		1523	
15	1	3.40	0.194	7.55		1888	5
	2	2.64	0.194	4.59		1148	
	3	3.86	0.264	7.19		1798	
16							0
17	1	6.50	0.293	18.2		4550	1
18							1
19	2	4.48	0.264	9.64		2410	4
	4	4.60	0.210	12.70		3175	
20	1	3.76	0.227	7.82		1955	3
	2	5.36	0.163	22.1		5525	
	3	2.76	0.192	5.05		1263	
21	2	6.96	0.247	24.6		6150	6
	6	3.26	0.240	5.66		1415	
	5	6.14	0.237	20.0		5000	
22	1	4.00	0.173	11.7		2925	3
	2	4.04	0.232	8.91		2228	
	3	4.46	0.209	12.0		3000	
23	1	5.92	0.209	21.1		5275	5
	2	3.48	0.232	6.64		1660	
	3	3.58	0.211	7.70		1925	
	5	4.24	0.228	9.97		2493	

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H. gauss	Hρ gauss cm.	Total No.
24							3
25	1	4.88	0.180	16.6	250	4150	3
	2	3.70	0.2[illegible]3	7.79		1948	
26							0
27	1	5.14	0.165	20.1		5025	3
	2	4.48	0.208	12.2		3050	
	3	3.16	0.252	5.08		1270	
28							2
29							0
30	2	5.64	0.280	14.3		3575	5
	3	5.28	0.200	17.5		4375	
	5	4.08	0.162	13.7		3425	
31	1	4.24	0.236	9.64		2410	5
	2	5.52	0.303	12.7		3175	
	3	2.92	0.292	3.80		950	
32	2	4.04	0.261	7.95		1988	2
33							2
34	1	5.72	0.163	15.8		3950	5
	2	4.46	0.209	12.0		3000	
	3	3.78	0.216	8.38		2090	
35							1
36							0
37	1	3.66	0.215	7.90		1975	3
	3	3.22	0.341	3.97		993	
38							1
39	4	4.60	0.300	8.97		2243	6
40							
41	under developed						
42							
(Roll No. 10)							
1	1	4.74	0.279	10.2		2550	4
	3	4.02	0.239	8.57		2143	
2							3
3							2
4	2	5.64	0.307	13.1		3275	6
	3	3.94	0.205	9.57		2393	
	5	5.10	0.190	17.2		4300	
	6	4.80	0.232	12.6		3150	

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H. gauss	$H\rho$ gauss cm.	Total No.
5	1	3.68	0.196	8.73	250	2183	2
	2	5.18	0.196	17.2		4300	
6	2	4.34	0.245	9.73		2433	4
	4	3.18	0.185	6.93		1733	
7	3	5.75	0.229	18.2		4550	4
	4	4.20	0.250	8.95		2238	
8	2	4.48	0.185	13.7		3425	3
9	2	5.04	0.286	11.2		2800	4
10	2	4.74	0.288	9.90		2475	4
	3	3.40	0.180	8.12		2030	
	4	3.96	0.278	7.19		1797	
11	2	5.14	0.210	15.8		3950	5
	3	2.60	0.217	4.00		1000	
	4	4.42	0.242	10.2		2550	
	5	2.46	0.260	3.04		760	
12	1	4.56	0.265	9.94		2485	4
	2	4.46	0.282	8.96		2240	
	3	4.22	0.156	14.3		3575	
	4	3.84	0.199	9.36		2340	
13	3	3.86	0.243	7.79		1947	5
	4	3.68	0.276	6.27		1568	
14	1	5.42	0.197	18.7		4675	4
	3	5.60	0.236	16.7		4175	
	4	6.06	0.264	17.5		4375	
15	2	4.54	0.203	12.8		3200	6
	3	3.32	0.151	9.20		2300	
16	2	4.72	0.279	10.1		2525	2
17	1	4.18	0.175	12.6		3150	5
	3	4.50	0.111	22.9		5725	
	5	4.36	0.251	9.59		2397	
18	2	6.04	0.200	22.9		5725	3
	3	4.50	0.265	9.68		2420	
19							3
20	1	3.40	0.204	7.19		1798	1
21	2	4.66	0.162	16.8		4200	3
22	1	4.58	0.281	9.47		2368	3
	2	4.30	0.207	11.3		2825	
	3	6.44	0.244	21.4		5350	
23							1
24							0
25							0

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H. gauss	Hρ gauss cm.	Total No.
(Roll No. 14)							
1	1	3.70	0.221	7.85	250	1968	4
2							4
3							2
4	2	4.84	0.276	10.7		2675	3
5	1	3.90	0.221	8.71		2178	3
	2	3.26	0.273	5.00		1250	
	3	6.56	0.278	19.5		4875	
6	1	4.18	0.275	8.08		2020	2
	2	3.16	0.338	3.86		915	
7							3
8	2	6.00	0.273	16.1		4025	3
9	1	3.56	0.315	5.29		1323	1
10	1	2.46	0.146	5.26		1315	3
	2	3.14	0.291	4.38		1095	
11	1	5.48	0.208	18.2		4550	2
12	1	4.48	0.226	11.2		2800	4
	2	3.86	0.190	9.90		2475	
	3	5.82	0.259	16.5		4125	
	4	2.94	0.210	5.25		1313	
13							2
14							2
15	2	5.66	0.181	22.2		5550	2
16	2	2.46	0.235	3.34		835	5
	5	2.94	0.203	9.66		2415	
17	2	4.20	0.175	12.7		3175	2
18	1	3.68	0.146	11.7		2925	1
19	1	5.90	0.191	22.9		5725	4
	3	3.88	0.240	7.96		1990	
	4	4.04	0.129	15.9		3975	
20							1
21	3	6.22	0.212	22.9		5725	4
22							3
23	1	4.90	0.178	16.9		4225	2
	2	4.90	0.177	17.0		4250	
24	1	4.46	0.202	12.4		3100	4
	2	3.28	0.120	11.3		2825	
	3	3.32	0.264	5.35		1338	
25	1	3.14	0.232	5.43		1358	3
26							3

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H, Gauss	$H\rho$ gauss cm.	Total No.
27	2	3.32	0.229	6.13	250	1333	3
	3	4.52	0.185	13.9		3470	
28	2	2.88	0.226	4.70		1175	3
	3	4.62	0.223	12.1		3025	
29	2	3.24	0.215	6.59		1648	4
	3	4.44	0.249	10.0		2500	
	4	2.28	0.181	3.68		920	
30	2	3.56	0.185	8.66		2165	4
	4	3.56	0.268	6.05		1513	
31	2	3.06	0.213	5.60		1400	4
32	1	4.44	0.231	10.8		2700	1
33	2	3.30	0.289	4.85		1213	2
34	3	3.62	0.215	7.72		1930	4
	2	3.86	0.221	8.54		2135	
35	2	5.38	0.298	12.3		3075	2
36	2	4.04	0.194	10.6		2650	4
	3	5.40	0.253	14.5		3625	
(Roll No. 15)							
1	3	6.80	0.201	28.9		7225	5
	4	3.64	0.236	7.14		1785	
2	1	5.06	0.206	15.6		3900	4
	2	4.76	0.209	13.7		3425	
	3	3.80	0.196	9.31		2328	
	4	6.24	0.255	19.2		4800	
3	1	5.14	0.250	13.3		3325	3
	2	3.40	0.309	4.83		1208	
	3	5.42	0.277	13.6		3400	
4	1	3.80	0.221	8.28		2070	2
	2	5.34	0.180	19.9		4975	
5	2	5.74	0.305	9.36		2340	2
6	1	4.06	0.154	13.5		3375	2
7							2
8	1	4.78	0.202	14.2		3550	2
	2	4.00	0.195	10.4		2600	
9	1	5.64	0.184	21.7		5425	3
	2	3.78	0.267	6.82		1705	
	3	5.16	0.325	10.4		2600	
10	1	2.90	0.148	7.18		1795	1
11	1	3.14	0.254	13.1		3275	4
	2	4.46	0.142	17.6		4400	

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H. Gauss	Hρ gauss cm.	Total No.
12							2
13	2	2.76	0.068	14.0	250	3500	4
	3	3.40	0.272	5.44		1360	
14	1	4.50	0.252	10.2		2550	3
15							2
16	2	5.00	0.220	14.3		3575	2
17	1	2.94	0.212	5.20		1300	3
	3	5.00	0.220	14.3		3575	
18	4	2.76	0.119	8.05		2013	5
	5	3.80	0.186	9.79		2448	
19							3
20							1
21							2
22	1	4.26	0.291	7.94		1985	3
	3	4.96	0.195	15.9		3975	
23	3	3.44	0.249	6.05		1513	5
	5	3.40	0.189	7.74		1935	
24							2
25	1	3.14	0.129	9.62		2405	1
26	2	4.82	0.223	12.6		3150	4
	4	4.42	0.179	13.7		3425	
27	4	3.66	0.197	8.60		2150	4
28	2	3.90	0.268	7.23		1808	2
29	1	3.12	0.210	5.90		1475	5
	2	4.70	0.278	10.1		2525	
	3	3.44	0.154	18.0		4500	
30	1	4.76	0.255	5.93		1583	3
	2	3.80	0.295	6.23		1558	
	3	5.18	0.267	12.7		3175	
31	2	2.56	0.205	4.10		1025	5
	3	5.14	0.282	11.9		2975	
	4	3.94	0.245	8.04		2010	
32	2	4.10	0.205	10.4		2600	4
33	1	4.92	01226	13.5		3375	1
34	1	4.38	0.208	11.6		2900	3
35	2	3.48	0.282	5.51		1378	4
	3	4.24	0.284	8.05		2013	
36	1	3.46	0.333	4.66		1165	2
	2	4.90	0.324	9.43		2358	

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H. gauss	Hρ gauss cm.	Total No.
37							2
38	3	6.48	0.181	29.1	250	7275	7
	4	2.80	0.275	3.70		925	
	5	4.56	0.240	11.0		2750	
	6	5.92	0.216	20.4		5100	
	7	5.46	0.299	12.6		3150	
(Roll No. 16)							
1	3	3.84	0.229	6.77		1793	4
2	3	3.86	0.222	8.50		2125	5
	4	4.74	0.226	12.5		3125	
	5	4.36	0.229	10.5		2625	
3	3	5.10	0.301	11.0		2750	3
4	1	4.24	0.237	9.60		2400	4
	2	5.66	0.259	15.6		3900	
5	2	5.62	0.236	16.8		4200	4
	3	3.76	0.216	8.28		2070	
	4	6.28	0.333	15.0		3750	
6							1
7	1	3.70	0.204	8.49		2123	4
	2	4.14	0.147	15.4		3850	
	3	2.88	0.228	4.66		1165	
8	1	4.70	0.305	9.20		2300	1
9	1	3.02	0.168	6.87		1718	4
10	2	5.54	0.211	18.3		4575	3
	3	6.24	0.289	17.0		4250	
11	3	4.52	0.277	9.35		2338	3
12	2	4.70	0.215	13.0		3250	3
13	3	4.30	0.270	8.69		2173	7
	4	4.76	0.200	14.3		3575	
	6	2.78	0.199	4.95		1238	
	7	2.90	0.206	5.20		1300	
14	3	3.52	0.259	6.11		1528	5
	5	3.00	0.203	5.64		1410	
15	2	4.04	0.201	10.2		2550	3
	3	4.04	0.274	7.58		1895	
16	2	2.78	0.228	4.35		1088	3
	3	5.22	0.337	10.3		2575	
17	1	4.54	0.259	10.1		2525	2
18	1	3.50	0.252	6.20		1550	2
	2	4.00	0.180	11.2		2800	

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H. gauss	$H\rho$ gauss cm.	Total No.
19	1	4.20	0.305	7.37	250	1843	4
	2	4.70	0.268	10.4		2600	
	3	5.82	0.272	15.7		3925	
	4	5.02	0.348	9.22		2305	
20	2	3.36	0.349	4.71		1178	7
	3	4.76	0.163	17.5		4375	
21	1	4.76	0.215	13.3		3325	3
22							1
23	2	3.84	0.134	13.8		3450	2
	1	3.80	0.227	8.06		2015	
24							1
25							2
26	3	3.76	0.310	5.85		1463	3
27	4	5.78	0.247	17.0		4250	5
(Roll No. 17)							
1							0
2							0
3	2	4.56	0.362	7.36		1840	2
4	1	2.56	0.213	3.95		988	2
	2	6.30	0.272	18.4		4600	
5							3
6	1	7.00	0.305	20.2		5050	3
	2	6.66	0.389	14.4		3600	
	3	4.24	0.295	7.76		1940	
7							0
8							1
9	1	4.74	0.300	9.51		2378	4
10							0
11	1	5.50	0.235	16.2		4050	1
12	1	6.36	0.348	14.2		3675	1
13	3	3.20	0.218	5.98		1495	4
14							3
15	1	5.66	0.284	14.2		3550	4
	2	4.00	0.236	8.59		2148	
16							4
17	1	5.56	0.330	11.9		2975	2
18	1	6.46	0.377	14.0		3500	2
19							3
20	2	5.30	0.236	15.0		3750	4
	4	3.44	0.263	5.75		1438	

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H, gauss	Hρ gauss cm.	Total No.
21	2	5.14	0.334	10.1	250	2525	2
22	1	6.50	0.222	23.9		5975	2
	2	6.40	0.304	17.0		4250	
23	1	4.62	0.300	9.04		2260	3
24	1	5.74	0.341	12.3		3075	5
	2	5.10	0.295	11.2		2800	
	3	4.84	0.362	8.26		2065	
	4	5.62	0.370	21.7		5425	
	5	4.72	0.385	7.42		1855	
25	2	6.26	0.215	22.9		5725	3
	3	6.86	0.438	13.6		3400	
26	1	5.74	0.266	15.6		3900	5
	3	5.72	0.283	14.6		3650	
27	3	6.64	0.264	21.0		5250	4
28	2	6.48	0.294	18.0		4500	4
	3	6.18	0.400	12.1		3025	
29	1	4.60	0.298	9.02		2255	3
	2	6.60	0.277	19.8		4950	
	3	5.36	0.353	10.3		2575	
30	1	7.80	0.316	24.2		6050	
31	3	6.80	0.272	21.4		5350	3
32	2	3.40	0.187	7.81		1953	4
	3	5.40	0.249	15.9		3975	
	4	4.92	0.237	12.9		3225	
33	1	4.82	0.252	11.6		2900	3
	3	5.00	0.279	11.3		2825	
34	3	4.76	0.326	8.85		2213	3
35	2	4.10	0.210	10.1		2525	3
	3	3.72	0.270	6.54		1635	
(Roll No. 18)							
1							0
2	1	3.64	0.297	5.72		1430	2
	2	4.18	0.218	10.1		2525	
3	1	5.40	0.258	19.3		4825	2
4	2	4.74	0.276	10.3		2575	2
5	1	3.90	0.195	9.84		2460	2
6							2
7	1	5.86	0.255	17.0		4250	2
	2	4.08	0.262	8.07		2018	
8	1	4.80	0.222	13.1		3275	1

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H. gauss	Hρ gauss cm.	Total No.
9	1	5.42	0.237	15.6	250	3900	3
	3	3.54	0.243	6.57		1643	
10	2	6.04	0.258	17.8		4450	2
11							1
12	2	5.42	0.228	16.2		4050	3
	3	6.26	0.320	15.5		3875	
13	3	5.50	0.326	11.8		2950	4
	4	2.80	0.270	3.76		940	
14							3
15							2
16	1	5.40	0.298	12.4		3100	5
	2	5.44	0.261	14.3		3575	
	3	3.82	0.270	6.89		1723	
	4	3.44	0.369	4.19		1048	
17	1	5.02	0.244	13.0		3250	1
18	1	6.06	0.259	17.9		4475	4
	2	5.06	0.229	14.1		3525	
	3	4.72	0.253	11.1		2775	
19	2	5.44	0.290	12.9		3225	4
	4	4.64	0.276	9.89		2473	
20							0
21							0
22	3	4.40	0.285	8.63		2158	3
23	3	4.16	0.370	6.03		1508	3
24							3
25	2	3.64	0.135	12.3		3075	3
	3	5.30	0.229	15.4		3850	
26	2	4.70	0.247	11.3		2825	3
27	1	5.02	0.261	12.2		3050	1
28							0
29							1
30	2	3.42	0.322	4.70		1175	4
	3	3.50	0.320	4.95		1238	
31	4	3.48	0.206	7.45		1863	
	1	3.02	0.180	6.42		1605	4
	3	3.06	0.175	6.78		1695	
	4	3.64	0.194	8.63		2158	
32							1
33	1	4.56	0.189	13.8		3450	2
34							0

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H. gauss	Hρ gauss cm.	Total No.
(Roll No. 19)							
1	1	5.16	0.229	14.6	250	3650	4
	2	4.76	0.315	9.15		2288	
2							2
3	1	5.66	0.276	14.6		3650	2
	2	5.40	0.337	11.0		2750	
4	1	3.46	0.247	6.18		1545	1
5	1	6.30	0.362	13.9		3475	2
	2	5.24	0.347	10.1		2525	
6	1	4.98	0.317	9.94		2485	2
7	2	6.50	0.361	14.8		3700	4
	3	4.00	0.360	5.74		1435	
8	2	6.40	0.286	18.0		4500	4
	4	6.54	0.314	17.2		4300	
9							1
10	2	4.00	0.364	5.68		1420	3
11	1	3.98	0.242	8.30		2075	3
12							2
13	3	5.14	0.329	10.2		2550	3
14	3	6.48	0.233	22.6		5650	3
15	3	4.84	0.178	16.5		4125	4
16							3
17	1	5.04	0.275	11.7		2925	3
	3	4.00	0.308	6.65		1663	
18	1	4.34	0.200	11.9		2975	2
19	2	4.74	0.317	7.59		1898	3
	3	3.36	0.151	9.42		2355	
20	1	7.24	0.334	19.8		4950	1
21							0
22	1	6.48	0.385	13.8		3450	2
23	1	5.98	0.314	14.4		3600	2
24	1	5.52	0.308	12.5		3125	1
25							2
26							0
27	2	6.40	0.323	16.0		4000	2
28	4	3.86	0.295	6.46		1615	4

Frame No.	Track No.	Chord Length Cm.	Sagitta cm.	ρ cm.	H gauss	Hρ gauss cm.	Total No.
(Roll No. 20)							
1	1	4.74	0.331	8.65	250	2163	2
	2	5.00	0.407	7.88		1970	
2							2
3							0
4	3	4.00	0.416	7.72		1935	3
5	1	2.86	0.286	3.72		935	4
	3	4.56	0.343	7.75		1938	
	4	4.82	0.124	23.5		5875	
6							1
7	1	3.66	0.143	11.8		2950	1
8	1	4.04	0.231	8.95		2238	5
	3	4.50	0.264	9.72		2435	
	4	3.74	0.227	7.82		1960	
	5	6.48	0.286	18.5		4625	
9	1	3.90	0.214	8.99		2248	3
	2	4.30	0.214	10.9		2725	
10	1	2.62	0.258	3.46		865	2
	2	5.05	0.160	20.1		5025	
11	1	3.04	0.307	3.92		985	3
	2	3.52	0.268	5.91		1478	
	3	3.68	0.202	8.48		2120	
12							3
13	2	5.90	0.241	18.2		4550	5
	4	4.06	0.310	6.80		1700	
14	1	5.92	0.145	30.2		7540	1
15	2	6.14	0.281	16.9		4225	6
	3	3.76	0.216	8.29		2073	
	4	4.14	0.217	9.98		2495	
	6	5.34	0.189	19.0		4750	
16	1	5.14	0.261	12.8		3200	3
	2	4.06	0.236	8.84		2210	
	3	2.74	0.262	3.71		928	
17	1	4.70	0.241	11.6		2900	4
	3	5.04	0.282	11.4		2850	
18	2	4.26	0.292	7.91		1978	4
	4	5.66	0.226	17.8		4450	
19	1	4.36	0.251	9.59		2398	2
20	1	4.20	0.243	9.20		2300	4

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	Hρ gauss cm.	Total No.
	2	5.20	0.258	13.2	250	3300	
	3	6.52	0.301	17.8		4450	
21	2	3.56	0.272	5.96		1490	2
22	2	5.42	0.285	13.0		3250	2
23							0
24							1
25	1	5.26	0.321	10.9		2725	2
26							1
27	2	3.92	0.224	8.69		2173	3
	3	5.84	0.213	20.1		5025	
28	2	5.68	0.347	11.8		2950	2
29	2	5.34	0.286	12.5		3125	2
30							1
31	1	6.60	0.362	12.6		3150	3
	3	5.14	0.276	19.9		4975	
32	1	6.34	0.288	17.6		4400	2
	2	5.44	0.276	13.5		3375	
33	1	6.10	0.276	17.0		4250	2
	2	5.12	0.386	8.68		2170	
34	1	6.74	0.306	18.7		4675	1
35							0
36							0
37	3	5.16	0.310	10.9		2725	3
38							0
(Roll No. 21)							
1 Double Exposure							
2							0
3							1
4	2	5.80	0.295	14.4		3600	2
5							3
6	2	4.82	0.213	13.7		3425	2
7							0
8	1	4.56	0.232	11.3		2825	2
	2	4.76	0.333	8.67		2168	
9	2	4.84	0.292	10.2		2550	3
10	2	2.80	0.398	2.66		665	3
	3	5.16	0.275	12.2		3050	
11	1	6.44	0.231	22.6		5650	2
	2	6.06	0.237	19.5		4875	
12	2	7.14	0.278	23.1		5775	4
	1	6.02	0.386	11.9		2975	

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	$H\rho$ gauss cm.	Total No.
13	1	3.12	0.267	4.69		1173	1
14							2
15							2
16	2	6.50	0.358	14.9		3725	4
	4	6.74	0.324	17.7		4425	
17							3
18							3
19	1	4.70	0.106	26.1		6525	2
	2	6.54	0.320	16.9		4225	
20							4
21	1	4.04	0.220	9.38		2345	3
	2	4.08	0.238	22.0		5500	
	3	5.00	0.306	10.4		2600	1
22	2	4.62	0.263	10.3		2575	3
	3	6.26	0.283	17.5		4375	
23	2	5.44	0.312	12.5		3125	3
	3	3.96	0.379	5.36		1340	
24							3
25	1	3.18	0.354	3.75		938	3
	3	5.82	0.343	12.5		3125	
26	1	7.36	0.438	16.5		4125	3
27	1	4.66	0.116	23.5		5875	4
	2	5.34	0.258	13.9		3475	
	3	3.96	0.339	5.95		1488	
28	1	3.78	0.250	7.27		1818	3
	3	4.74	0.362	7.94		1985	
29							0
30	1	6.04	0.274	16.8		4200	3
	2	4.36	0.414	5.95		1488	
31	1	6.30	0.333	15.1		3775	2
32							0
33	3	5.38	0.395	9.36		2340	3
(Roll No. 22)							
1	1	4.12	0.314	6.92		1730	2
2							1
3	1	2.54	0.171	4.80		1200	2
4	1	3.64	0.348	4.93		1233	2
5	1	3.66	0.360	5.09		1273	3
	3	6.62	0.434	12.8		3200	
6	3	4.60	0.186	15.6		3900	4
	4	6.80	0.310	18.8		4700	
7							0

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	Hρ gauss cm.	Total No.
8	2	5.14	0.226	18.6	250	4650	3
	3	5.06	0.376	8.92		2230	
9							2
10	1	3.54	0.184	8.61		2153	2
	2	5.36	0.335	10.9		2725	
11							1
12							1
13	1	3.90	0.358	5.49		1373	3
	2	4.18	0.230	9.61		2403	
	3	5.20	0.244	14.0		3500	
14							1
15	1	4.84	0.217	13.6		3400	1
16	1	3.00	0.593	2.19		5485	1
17							6
	2	4.66	0.208	13.2		3300	
	3	5.52	0.233	16.5		4125	
	4	3.52	0.255	6.20		1550	
	5	6.40	0.349	14.8		3700	
18	1	5.02	0.232	13.7		3425	1
19	1	4.28	0.338	6.94		7735	1
20	1	5.36	0.318	11.5		2875	2
	2	5.12	0.154	21.4		5350	
21	1	6.18	0.309	15.6		3900	1
22							0
23	2	5.40	0.283	13.0		3250	3
24	2	5.22	0.225	15.3		3825	3
	3	7.28	0.655	10.4		2600	
25	1	6.10	0.286	16.4		4100	1
26							2
27							0
28	1	6.12	0.500	9.61		2403	1
29	1	5.18	0.354	9.65		2413	1
30	1	3.94	0.121	16.1		4025	1
31	1	6.60	0.359	15.3		3825	3
	2	6.30	0.476	10.7		2675	
	3	6.40	0.356	14.6		3650	
32							2

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	Hρ gauss cm.	Total No.
(Roll No. 23)							
1	1	4.30	0.159	14.6	250	3650	2
2	1	3.54	0.198	8.01		2003	3
	2	4.66	0.293	8.63		2158	
	3	5.88	0.236	18.4		4600	
3	1	5.04	0.247	13.0		3250	2
	2	4.78	0.262	11.0		2750	
4	1	7.20	0.185	35.1			1
5	1	3.70	0.285	20.3		5075	3
	3	5.52	0.277	13.9		3475	
6	1	6.60	0.367	15.0		3750	1
7	1	5.62	0.280	14.2		3550	2
8	1	5.26	0.263	13.3		3325	3
9	1	2.48	0.186	4.23		11[illegible]3	2
10	1	3.78	0.217	8.34		2185	4
	2	5.42	0.284	13.1		3275	
	4	4.68	0.354	7.91		1978	
11							0
12							2
13	2	4.94	0.287	10.8		2700	2
14							3
15							2
16	2	5.40	0.274	13.4		3350	3
	3	2.34	0.232	3.07		768	
17	2	3.34	0.326	4.44		1110	3
	3	5.86	0.236	18.3		4575	
18	2	4.88	0.251	12.0		3000	3
19	1	4.86	0.263	11.4		2850	2
20	1	4.32	0.280	8.47		2118	4
	4	4.68	0.219	12.6		3150	
21							1
22	1	4.86	0.199	14.9		3725	3
	2	5.32	0.261	13.7		3425	
23	1	2.84	0.281	3.78		945	1
24	1	6.50	0.179	29.6		7400	3
	2	3.24	0.265	5.08		1270	
	3	5.00	0.348	9.15		2278	
25	1	4.26	0.193	11.9		2975	3
	2	4.90	0.224	13.5		3375	
26	1	4.26	0.240	9.57		2393	3
	3	4.78	0.259	11.2		2800	

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	$H\rho$ gauss cm.	Total No.
27	3	4.04	0.265	7.82	250	1955	3
28	1	4.54	0.188	13.8		3450	2
	2	4.04	0.227	9.10		2275	
29	1	3.08	0.213	5.67		141[illegible]	1
30	1	4.06	0.251	8.02		2005	3
	3	3.28	0.446	3.24		810	
31							1
32	1	4.86	0.261	11.4		2850	5
	2	7.08	0.312	20.2		5050	
	3	4.54	0.167	15.5		3875	
	4	3.30	0.192	7.18		1795	
	5	3.76	0.218	8.21		2053	
33	2	5.62	0.223	18.1		4525	2
(Roll No. 24)							
1							2
2							1
3							1
4							2
5	1	4.72	0.236	11.9		2975	2
6							0
7	1	2.72	0.243	3.93		983	1
8	1	6.42	0.210	24.6		6150	2
	2	2.44	0.195	3.91		978	
9							1
10	1	3.86	0.306	6.24		1560	4
	2	3.90	0.319	6.11		1528	
	3	4.28	0.251	9.24		2310	
	4	6.36	0.263	19.4		4850	
11							1
12							1
13							2
14	1	3.56	0.261	6.19		1548	4
	2	3.30	0.235	5.90		1475	
	3	2.56	0.223	3.78		945	
	4	5.44	0.246	15.2		3800	
15	1	5.10	0.280	11.8		2950	1
16							2
17	1	6.48	0.381	14.0		3500	4
	2	3.08	0.199	6.05		1513	
	3	3.16	0.210	6.04		1510	
18							0
19							2

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	$H\rho$ gauss cm.	Total No.
20	1	3.44	0.240	6.28	250	1570	2
21	1	4.78	0.359	8.13		2033	2
22	1	2.56	0.222	3.80		950	2
	2	3.86	0.253	7.48		1870	
23	2	5.36	0.298	12.2		3050	2
24							0
25	1	5.16	0.209	16.0		4000	3
	3	4.74	0.257	14.9		3725	
26	1	7.72	0.403	18.7		4675	3
	3	6.04	0.316	14.5		3625	
27	1	5.10	0.273	12.0		3000	3
	2	4.82	0.254	11.6		2900	
28							3
29							3
30	1	5.06	0.423	7.77		1943	5
	3	3.54	0.310	5.20		1300	
	4	3.72	0.266	6.63		1658	
31							3
32	1	4.22	0.304	7.47		1868	4
	2	2.88	0.193	5.47		1368	
	3	5.18	0.268	12.6		3150	
	4	5.16	0.343	9.87		2468	
33							3
34							0
35	1	5.16	0.252	13.3		3325	3
	2	4.10	0.307	6.99		1748	
	3	3.22	0.371	3.67		918	
(Roll No. 25)							
1	1	3.10	0.365	3.47		868	1
2	1	5.00	0.345	9.23		2308	2
	2	6.28	0.222	22.3		5575	
3	1	6.56	0.328	16.6		4150	3
	2	7.30	0.441	15.3		3825	
	3	3.48	0.254	6.09		1523	
4	1	3.38	0.141	10.2		2550	2
	2	2.80	0.179	5.56		1390	
5							2
6	Double Exposure						
7	1	2.56	0.379	2.35		588	5
	2	5.34	0.306	11.8		2950	
	4	5.48	0.331	11.5		2875	
	5	3.46	0.359	4.35		1088	

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	Hρ gauss cm.	Total No.
8	1	4.94	0.242	12.7	250	3175	4
	2	5.00	0.352	9.05		2263	
9	1	4.42	0.293	8.48		2120	3
10							0
11							1
12	1	6.54	0.359	15.1		3775	3
	2	3.84	0.249	7.53		1883	
	3	2.90	0.163	6.53		1633	
13	1	2.80	0.341	3.04		760	2
	2	6.66	0.262	21.3		5325	
14	1	3.86	0.276	6.89		1723	2
	2	4.16	0.232	9.44		2360	
15							0
16	1	3.62	0.212	7.83		1958	3
	3	3.64	0.085	19.5		4875	
17	1	3.74	0.283	6.32		1580	2
	2	5.04	0.231	13.9		3475	
18	1	6.26	0.249	19.3		4825	3
	2	4.96	0.222	14.0		3500	
19	1	5.10	0.289	11.4		2850	3
	3	3.82	0.242	7.65		1913	
20	1	4.38	0.256	9.50		2375	3
	2	3.94	0.152	12.8		3200	
21							3
22	2	2.86	0.223	4.70		1175	5
	3	2.90	0.176	6.06		1515	
	4	3.80	0.227	8.07		2018	
23	1	3.60	0.166	9.84		2460	1
24	1	5.12	0.223	14.8		3700	3
25	1	2.68	0.344	2.78		695	2
26	3	5.00	0.284	11.1		2775	4
27	2	4.62	0.308	8.82		2205	3
28							3
29							2
30							3
31	1	3.32	0.327	4.38		1095	2
	2	4.76	0.321	8.98		2245	
32	2	3.70	0.304	5.78		1445	5
	3	2.46	0.210	3.71		928	
	4	3.92	0.290	6.77		1693	
	5	5.44	0.444	8.55		2138	
33	1	4.84	0.335	8.91		2228	2
	2	4.78	0.352	8.29		2073	
34							0

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	$H\rho$ gauss cm.	Total No.
(Roll No. 26)							
1	2	6.62	0.296	18.7	250	4675	4
	4	6.04	0.338	13.7		3425	
2	1	3.54	0.302	5.34		1335	5
	3	5.88	0.302	14.5		3625	
3							1
4	1	3.70	0.184	9.39		2348	3
	3	5.92	0.255	17.3		4325	
5	1	4.52	0.175	14.7		3675	4
	3	6.38	0.375	13.8		3450	
	4	5.02	0.366	8.79		2198	
6	2	4.38	0.375	6.58		1645	4
	3	5.74	0.280	14.8		3700	
	4	5.00	0.212	14.8		3700	
7	1	5.30	0.252	13.6		3400	3
	2	6.96	0.329	18.6		4650	
	3	6.02	0.240	19.0		4750	
8	2	4.12	0.291	7.44		1860	5
	3	6.46	0.274	19.2		4800	
	4	3.60	0.319	5.24		1310	
	5	3.04	0.387	3.18		795	
9	2	4.00	0.353	5.84		1460	3
10	2	5.50	0.381	10.2		2550	2
11	2	4.88	0.247	12.2		3050	4
	3	4.26	0.316	7.34		1835	
12	1	5.44	0.241	15.5		3875	5
	2	3.86	0.297	6.42		1605	
	3	5.40	0.279	13.2		3300	
	4	5.66	0.347	11.7		2925	
13	1	4.78	0.274	10.6		2650	4
	3	3.42	0.292	5.45		1363	
14	2	5.36	0.269	9.92		2480	3
15	1	6.34	0.293	17.3		4325	2
	2	6.14	0.257	18.5		4625	
16	2	4.96	0.221	14.0		3500	3
	3	2.58	0.375	2.41		603	
17	1	5.54	0.219	17.6		4400	2
	2	2.76	0.206	4.72		1180	
18	1	4.60	0.301	8.94		2235	5
	2	5.42	0.315	11.8		2950	
	4	4.80	0.258	11.3		2825	

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	Hρ gauss cm.	Total No.
19	1	5.86	0.282	15.4	250	3850	3
	2	3.22	0.342	3.96		990	
20	1	4.02	0.238	8.61		2153	2
21	2	3.90	0.361	5.45		1363	3
	3	3.94	0.298	6.66		1665	
22	3	4.64	0.242	11.2		2800	4
23	3	4.64	0.200	13.6		3400	5
	4	3.94	0.188	10.4		2600	
	5	4.88	0.194	15.4		3850	
24	2	4.76	0.343	8.43		2108	2
25	3	5.24	0.303	11.5		2875	3
26							7
	5	4.80	0.327	8.97		2243	
	6	5.78	0.291	14.5		3625	
	7	4.38	0.306	7.99		1998	
27	1	4.86	0.226	13.4		3350	4
	3	5.92	0.421	10.6		2650	
	4	6.14	0.481	10.0		2500	
28	1	3.94	0.328	6.08		1520	2
29	3	4.34	0.177	13.4		3350	3
30							3
31							1
32	2	4.74	0.333	8.61		2153	3
	3	6.00	0.313	14.5		3625	
33							
(Roll No. 27)							
1	2	3.50	0.237	6.58		1645	5
	3	4.34	0.353	7.48		1870	
	4	5.02	0.347	9.25		2313	
	5	3.86	0.256	7.40		1850	
2	1	3.64	0.367	4.70		1175	6
	3	4.36	0.201	11.9		2975	
	4	4.16	0.379	5.90		1475	
	5	5.94	0.281	15.8		3950	
	6	4.00	0.228	8.89		2223	
3	2	5.46	0.405	9.40		2350	3
4	2	3.74	0.204	8.67		2168	3
5							0
6	2	7.16	0.228	28.2		7050	5
	3	4.40	0.209	11.7		2925	

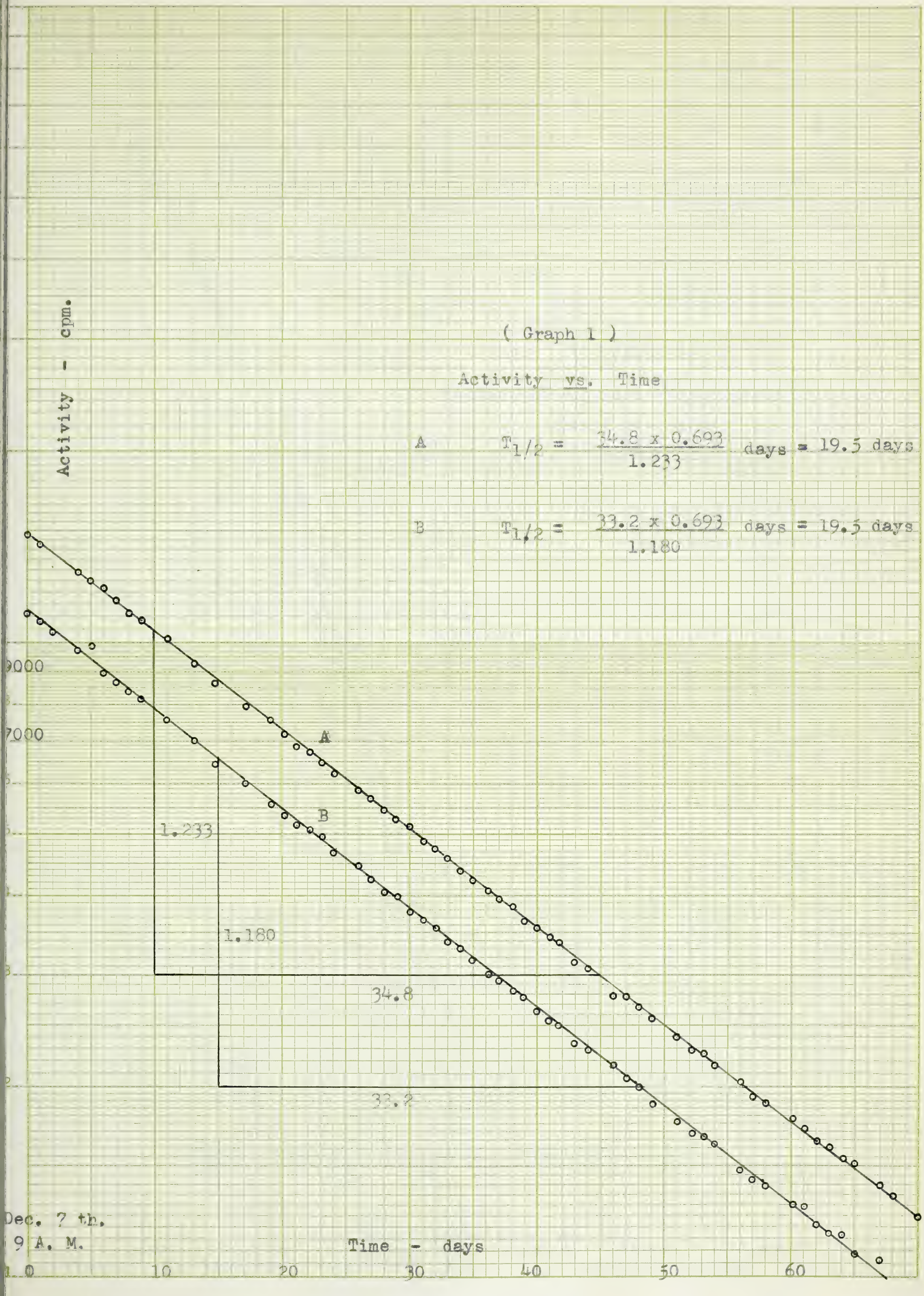
Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	Hρ gauss cm.	Total No.
7	2	6.18	0.244	19.7	250	4925	6
	3	4.68	0.234	11.8		2950	
	4	7.04	0.253	24.5		6125	
	5	5.70	0.393	10.5		2625	
	6	4.64	0.159	17.0		4250	
8	1	3.44	0.216	6.96		1740	3
	2	4.06	0.310	6.80		1700	
9	2	4.56	0.216	12.1		3025	2
10	2	3.44	0.165	9.05		2263	2
11	2	6.84	0.290	20.3		5075	3
12							0
13							3
14							3
15	1	4.34	0.355	6.81		1703	2
	2	3.86	0.[illegible]61	6.48		1620	
16							2
17	2	6.46	0.321	16.4		4100	3
	3	6.16	0.245	19.5		4875	
18	3	4.84	0.350	8.54		2135	3
19	4	5.60	0.293	13.5		3375	4
20	1	4.30	0.284	8.28		2070	1
21							0
22	1	3.72	0.253	6.96		1740	1
23							2
24							2
25	2	4.40	0.378	6.59		1648	4
	3	4.88	0.384	7.94		1985	
	4	4.78	0.311	19.3		4825	
26	2	5.80	0.290	16.6		4150	2
27	1	4.08	0.227	9.28		2320	3
	2	5.90	0.315	14.0		3500	
	3	3.04	0.275	4.34		1085	
28	1	4.90	0.283	10.7		2675	4
	2	5.60	0.366	10.9		2725	
29							0
30	1	7.24	0.249	26.4		6600	5
31	2	3.58	0.364	4.58		1145	3
32	2	4.34	0.243	9.81		2453	4
	3	6.68	0.387	14.6		3650	
	4	3.80	0.328	5.67		1418	

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	Hρ gauss cm.	Total No.
33	2	3.90	0.292	6.66	250	1665	3
34	1	4.10	0.333	6.48		1615	3
	2	4.70	0.340	8.29		2073	
	3	5.48	0.312	12.2		3050	
35							
36	1	3.96	0.262	7.61		1903	3
	2	4.06	0.262	8.00		2000	
37							1
(Roll No. 28)							
1	1	3.66	0.500	3.59		898	3
2	1	5.44	0.295	12.7		3175	4
	2	7.06	0.207	30.2		7550	
3	4	6.00	0.319	14.3		3575	4
4	1	3.74	0.375	4.84		1210	4
	2	6.30	0.287	17.4		4350	
5	2	3.90	0.215	7.27		1818	5
	4	4.52	0.437	6.05		1513	
	5	2.34	0.345	2.15		538	
6							2
7	1	4.88	0.288	10.5		2625	1
8	1	3.62	0.176	9.39		2348	4
	2	3.80	0.291	6.34		1585	
	4	4.00	0.333	6.17		1543	
9	1	4.62	0.224	12.0		3000	2
10	1	5.34	0.361	10.1		2525	1
11							3
12	1	5.62	0.277	14.4		3600	2
13	1	5.70	0.326	12.6		3150	3
14	3	7.40	0.162	4.30		1075	4
	4	4.18	0.350	6.41		1603	
15	2	5.66	0.299	13.5		3375	2
16	2	3.58	0.309	5.33		1333	3
	3	4.66	0.308	8.96		2240	
17	3	4.32	0.261	9.06		2265	3
18	1	3.04	0.182	6.43		1608	3
	2	5.52	0.252	15.2		3800	
	3	4.12	0.194	11.0		2750	
19	1	1.96	0.175	2.83		708	1
20	1	5.74	0.230	18.0		4500	3
21	2	4.44	0.342	7.38		1845	4
	4	4.36	0.275	8.77		2188	

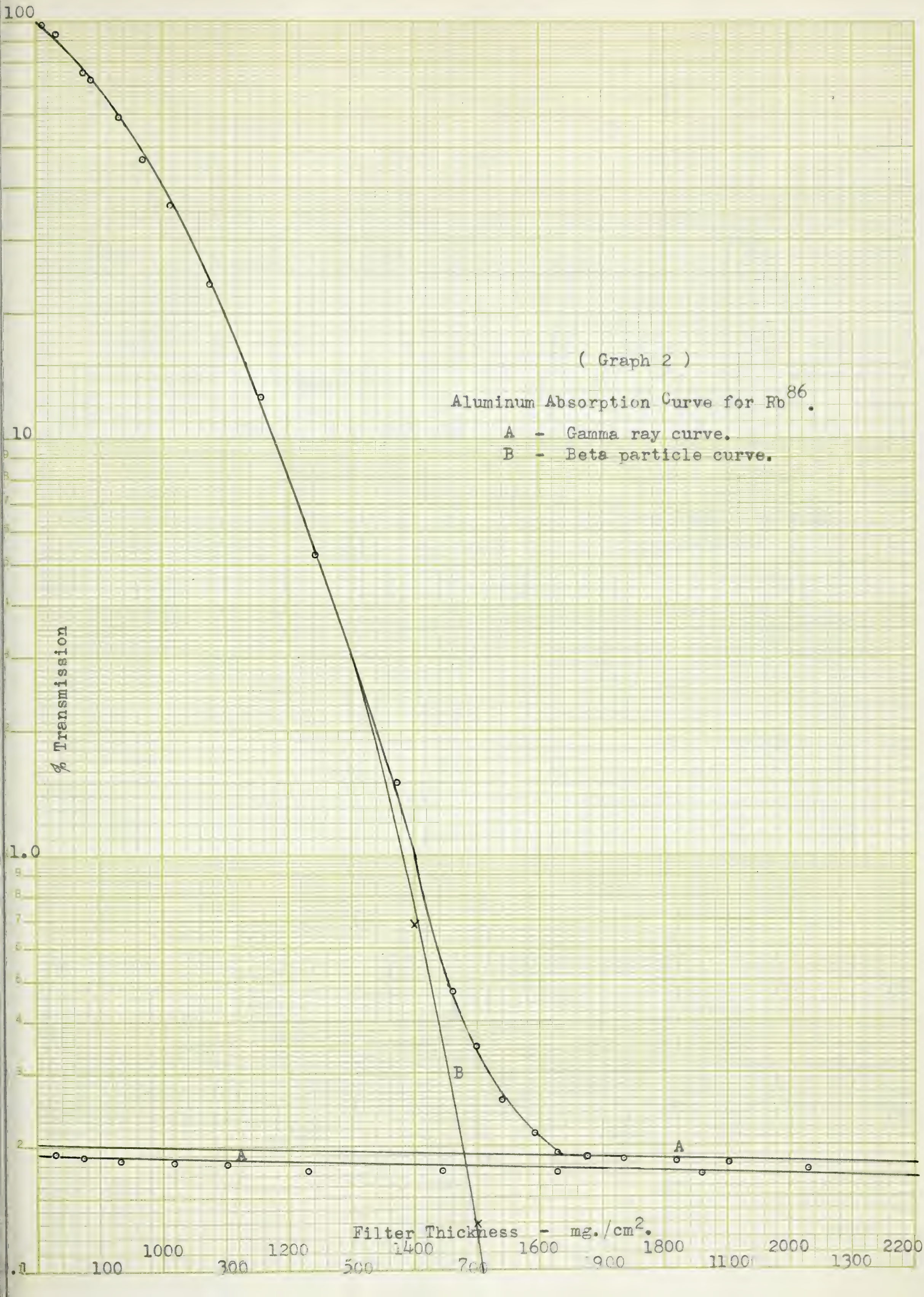
Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	Hρ gauss cm.	Total No.
22	2	5.12	0.338	9.86	250	2465	4
	4	2.64	0.231	3.88		970	
23							0
24	2	5.32	0.311	12.4		3100	3
	3	7.06	0.299	21.0		5250	
25	2	3.54	0.162	9.75		2438	4
26	1	6.68	0.351	16.1		4025	1
27	1	4.34	0.335	7.20		1800	3
28	2	3.42	0.333	4.56		1140	6
	3	5.72	0.290	14.2		3550	
	4	4.92	0.373	8.30		2075	
	6	4.66	0.297	9.29		2323	
29	1	6.44	0.195	26.7		6675	3
	2	7.20	0.198				
30	2	5.10	0.324	10.2		2550	3
31	2	5.22	0.299	11.5		2875	4
	3	3.84	0.317	5.97		1488	
32							1
33	1	5.24	0.447	7.90		1975	3
	2	5.32	0.322	11.1		2775	
	3	4.72	0.256	11.0		2750	
34	3	4.40	0.189	12.1		3025	6
	4	4.72	0.217	12.9		3225	
	5	6.62	0.370	15.0		3750	
	6	4.66	0.186	14.7		3675	
35	1	5.90	0.261	16.8		4200	3
36							1
37	1	5.52	0.228	16.8		4200	1
(Roll No. 29)							
1	1	3.64	0.226	7.44		1860	2
	2	5.04	0.316	10.2		2550	
2	1	8.24	0.329				1
3							3
4	1	5.30	0.360	26.0		6500	1
5	1	3.90	0.284	12.5		3125	3
	3	5.20	0.327	16.5		4125	
6	1	4.16	0.246	8.97		2238	4
	2	7.04	0.295	21.1		5275	
	3	4.16	0.275	8.00		2000	
7							0
8	1	2.40	0.277	2.74		685	2

Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	Hρ gauss cm.	Total No.
9							2
10	3	6.06	0.259	17.9	250	4475	4
	4	3.04	0.252	4.71		1178	
11	2	4.06	0.314	6.72		1680	6
	4	5.10	0.332	9.96		2490	
	5	4.10	0.301	7.13		1783	
	6	6.34	0.301	16.8		4200	
12							2
13	3	3.26	0.480	3.01		753	3
14	1	3.44	0.310	4.93		1233	3
	2	5.76	0.325	12.9		3225	
	3	5.50	0.400	9.65		2413	
15	2	6.90	0.333	18.0		4500	2
16	1	4.02	0.392	5.35		1338	2
	2	5.96	0.272	16.5		4125	
17	2	5.44	0.333	11.3		2825	5
	3	5.62	0.262	15.2		3800	
	5	5.78	0.397	10.7		2675	
	4	4.20	0.249	8.98		2245	
18							1
19	3	6.64	0.386	14.7		3675	5
	4	7.26	0.396	16.8		4200	
	5	2.54	0.261	3.22		805	
20	1	6.14	0.337	14.2		3550	2
	2	4.58	0.408	6.63		1658	
21	1	5.42	0.402	9.34		2335	2
22	1	4.62	0.287	9.44		2360	3
	2	6.62	0.290	19.0		4750	
	3	4.96	0.246	12.6		3150	
23	1	4.67	0.444	6.39		1598	3
	2	5.14	0.330	10.2		2550	
	3	4.92	0.299	10.3		2575	
24	1	4.44	0.368	6.88		1720	1
25							1
26	1	7.14	0.392	16.5		4125	3
27	1	5.40	0.376	9.88		2470	1
28							2

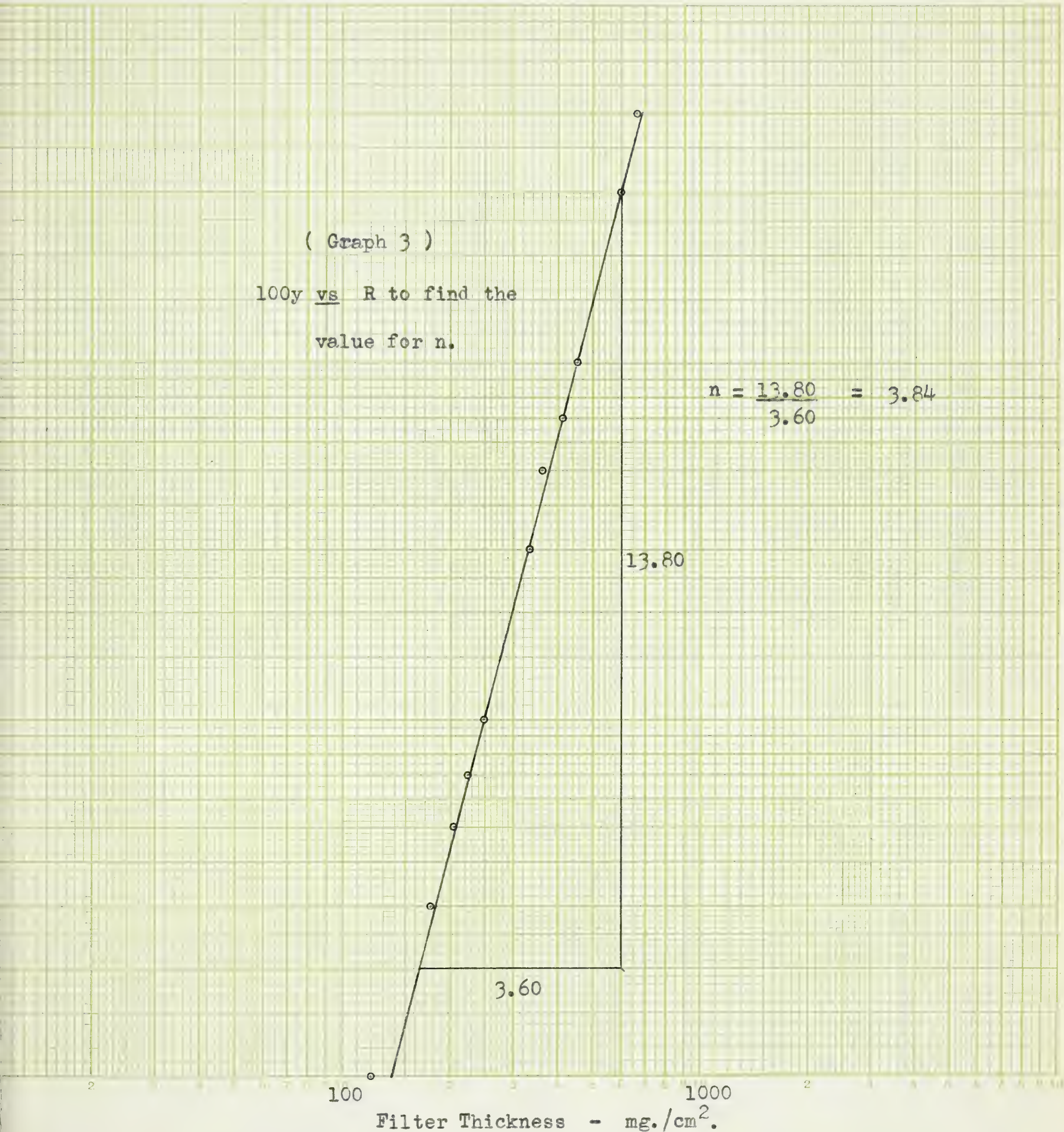
Frame No.	Track No.	Chord Length cm.	Sagitta cm.	ρ cm.	H gauss	Hρ gauss cm.	Total No.
(Roll No. 13							
1							0
2							0
3	1	4.62	0.344	7.93	250	1983	3
	2	3.54	0.122	12.9		3225	
	3	3.00	0.273	4.26		1065	
4	1	5.[illegible]	0.331	12.9		3225	4
	3	5.28	0.447	8.02		2005	
	4	6.06	0.353	13.2		3300	
5							3
6	1	3.00	0.193	5.93		1483	2
7	1	5.40	0.399	6.82		1705	5
	4	5.84	0.256	16.8		4200	
8							2
9							1
10	1	4.62	0.218	12.3		3075	1
11	1	4.86	0.410	7.21		1803	3
	2	7.22	0.420	15.7		3925	
12							2
13	3	5.26	0.309	11.3		2825	4
	4	3.28	0.363	3.89		973	
14	1	5.80	0.406	10.6		2650	5
	2	5.20	0.443	7.85		1963	
	3	5.40	0.386	9.64		2410	
	4	5.36	0.383	9.57		2393	
15	2	6.10	0.379	12.5		3125	4
	3	5.34	0.318	11.4		2850	
	4	3.36	0.280	5.18		1295	
16							3
17							2
18							3
19							2
20	1	7.56	0.399	18.3		4575	1
21							2
22	1	6.74	0.339	16.9		4229	3
23	1	8.30	0.307	28.2		7050	1
24	2	2.86	0.330	3.26		815	3
25	2	4.40	0.330	8.00		2000	3
	3	7.30	0.338	19.9		4975	
26	1	7.16	0.245	26.3		6575	3
(Roll No. 12)							
13	1	5.76	0.170	32.0		8000	3
	3	6.38	0.340	15.1		3775	
20	1	6.18	0.515	9.52		2380	1
26	2	6.12	0.490	9.80		2450	2
29	2	8.74	0.346	27.8		6950	3
31	2	7.76	0.403	18.9		4725	2

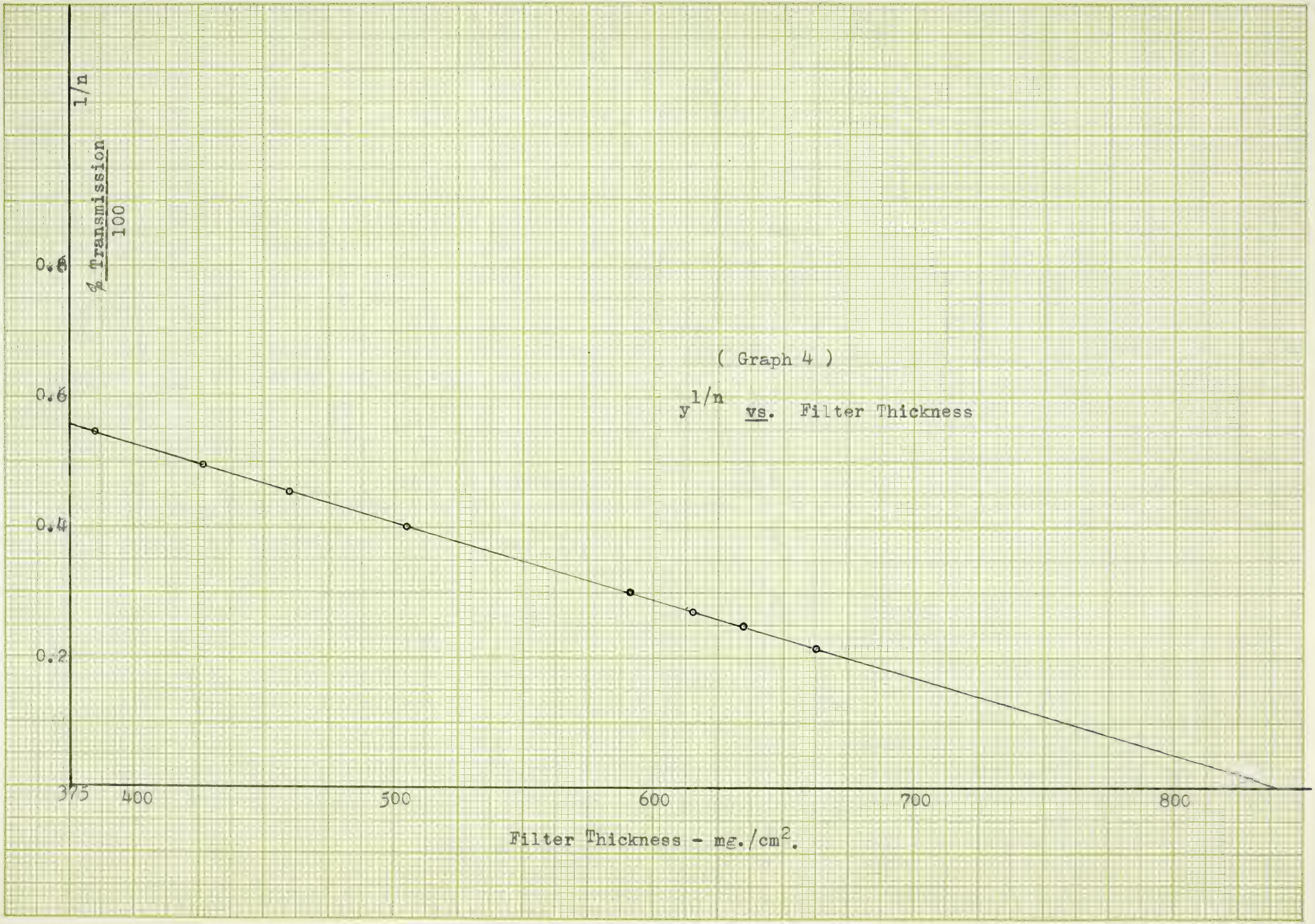


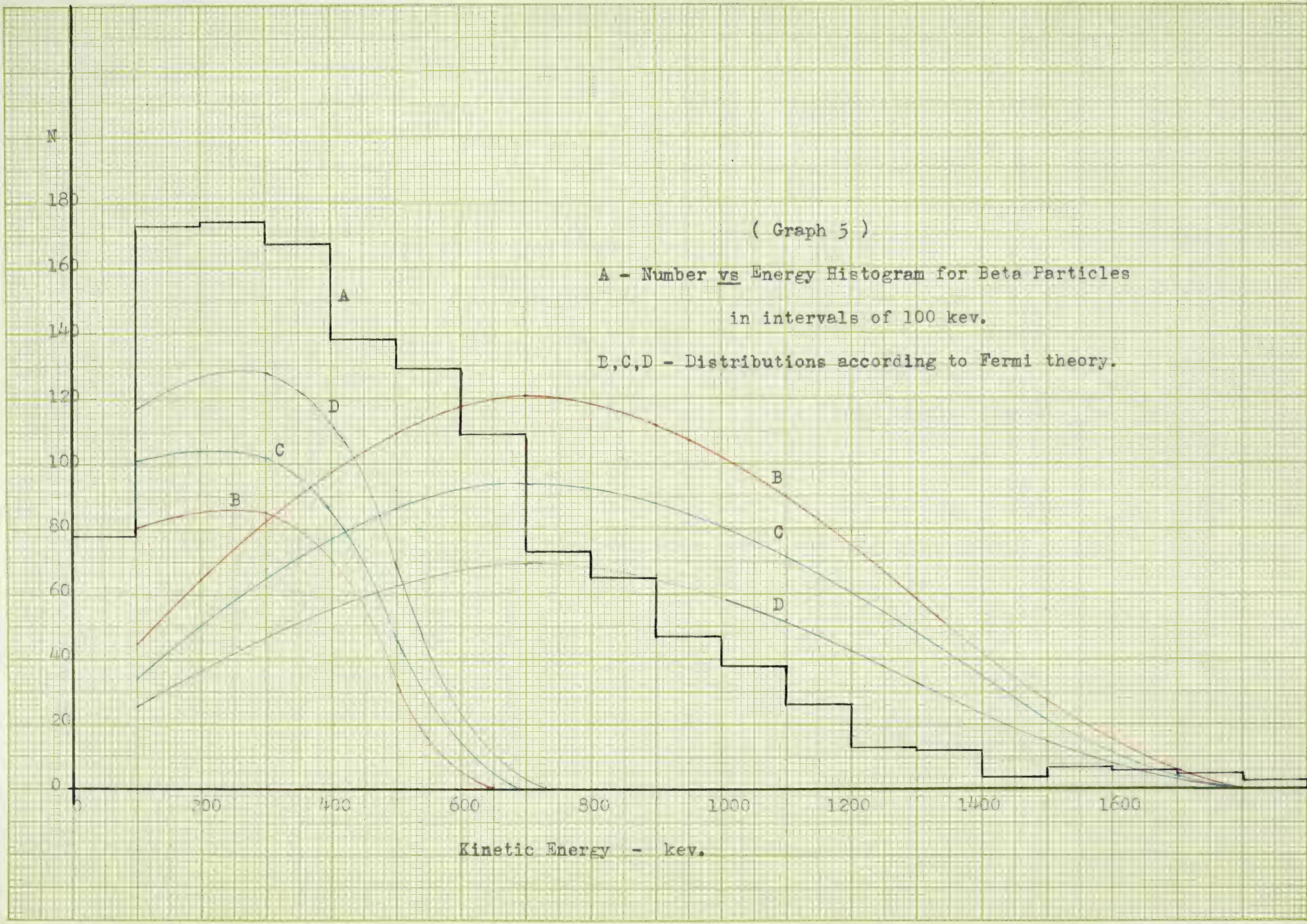
(Graph 1)
Activity vs. Time
A $T_{1/2} = \frac{34.8 \times 0.693}{1.233}$ days = 19.5 days
B $T_{1/2} = \frac{33.2 \times 0.693}{1.180}$ days = 19.5 days
Activity - cpm.
9000
7000
A
B
1.233
1.180
34.8
33.2
Dec. 7 th.
9 A. M.
Time - days
0
10
20
30
40
50
60

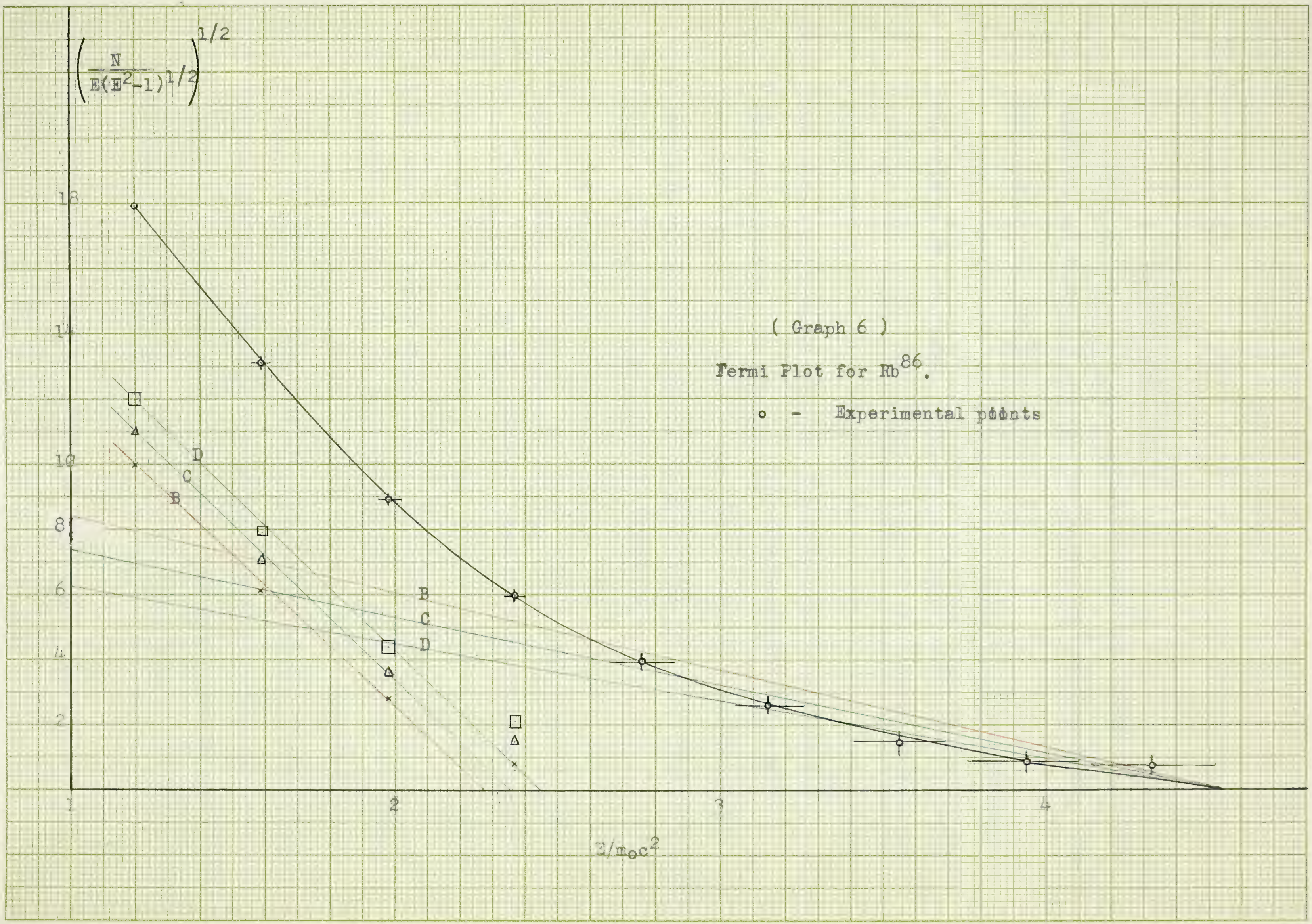


(Graph 2)
Aluminum Absorption Curve for Rb[86].
A - Gamma ray curve.
B - Beta particle curve.
% Transmission
Filter Thickness - mg./cm^2.
100
10
1.0
.1
A
B
1000
1200
1400
1600
1800
2000
2200
100
300
500
700
900
1100
1300


(Graph 3)
100y vs R to find the
value for n.
n = 13.80 / 3.60 = 3.84
13.80
3.60
100
1000
Filter Thickness - mg./cm2.


(Graph 4)
y^1/n vs. Filter Thickness
1/n
% Transmission / 100
0.6
0.4
0.2
375
400
500
600
700
800
Filter Thickness - mg./cm².


(Graph 5)
A - Number vs Energy Histogram for Beta Particles
in intervals of 100 kev.
B,C,D - Distributions according to Fermi theory.
N
180
160
140
120
100
80
60
40
20
0
A
B
C
D
0
200
400
600
800
1000
1200
1400
1600
Kinetic Energy - kev.



(Graph 6)
Fermi Plot for Rb^{86}.
o - Experimental points
$\left(\frac{N}{E(E^2-1)^{1/2}}\right)^{1/2}$
18
14
10
8
6
4
2
1
2
3
4
E/m_oc^2
B
C
D
B
C
D

Experimental Results

The decay curves for both samples were plotted. (Graph 1). The half-life was calculated and found to be 19.5 days in both cases. This value agrees with the value given by (4).

From the aluminum absorption curve a maximum range of 840 mg/cm^2 was assumed for the higher energy beta particles. Following the method given by Katz, et al, (10) a plot was made of the percent transmission against $R_0' - R$ on log-log paper (Graph 3). The slope of the straight line gave a value for n of 3.44. Using this value a plot of $y^{1/n}$ against R was made, and extrapolation yielded the value for R_0'' of 840 mg/cm^2 (Graph 4). The maximum range for the higher energy beta-particles was therefore taken to be 840 mg/cm^2, and the energy corresponding to this range is 1.80 mev. by Feather's rule.

The energy spectrum corresponding to 1265 acceptable cloud-chamber tracks was plotted. (Graph 5). Fermi's theory was applied to this histogram and the resulting curve is shown. (Graph 6). As was to be expected, since the higher energy transition of Rb^{86} lies on the second forbidden Sargent curve, the points corresponding to the higher energy group did not lie on a straight line. To interpret the curve, the value 1.80 mev, as obtained from the absorption measurements, was taken as end-point energy for the higher energy group. Three straight lines were drawn from this point, (B,C,D, Graph 6) within the calculated tolerances of the points (Appendix 2). Subtraction from the rest of the Fermi plot yielded three straight lines corresponding to the lower energy

group. The end-point was found to be 0.69 ± 0.05 mev. The distributions according to these straight lines were plotted back on graph 5. The lower energy group was found to comprise 20 ± 4% of the total number of disintegrations measured.

The gamma ray should have an energy of 1.11 ± 0.05 mev by subtracting the lower maximum energy from the higher, but there was no check on this value since the range of absorbers available did not permit an accurate calculation of this energy. The gamma ray curve (B, graph 2) gives an approximate energy of 0.8 mev for the gamma ray. Even with the large increase in source activity the counting rate was still much too low for accuracy. A 1.1 mev. gamma ray would simply make the gamma ray curve approach a horizontal line and would not affect the chosen value for R_o.

Discussion

Although graph 6 shows the calculated tolerances in the points for the Fermi plot, several other factors might affect these points. From the distribution curve there seems to be a large excess of low energy tracks with an energy of approximately 0.3 mev., and a noticeable absence of tracks with an energy between 0.9 mev. and 1.3 mev. A second forbidden transition is known to have an energy distribution which is skewed in the direction of low energies. Also the complex disintegration scheme of Rb^{86} would naturally result in an asymmetric

distribution. The Bragg ionization curve for electrons indicates a minimum specific ionization for 1 mev electrons. For lower energies, the specific ionization increases sharply, whereas for higher energies the value is fairly constant. A 1.1 mev. beta particle, for example, loses approximately 16 kev. traversing a 10 cm. air path, whereas a 0.1 mev. particle loses approximately 29 kev. in traversing a 7 cm. air path. Our method of calculating the energy would most certainly have an error for each energy of the order of one half this energy loss, and increasing for lower energy particles. Thus loss of energy due to this effect would shift the distribution slightly to the left by an amount which increases toward low energy. Little difficulty was experienced in measuring tracks with an energy around 0.3 mev. These tracks showed very little ion diffusion and were in most cases between 5 and 8 cm. long. The higher energy tracks were mostly of the order of 10 cm. long and, of course, were sparsely ionized. A large number of these tracks had to be discarded because of uncertainity as to their origin and because of noticeable deflections due to scattering. The use of hydrogen in the chamber instead of air would certainly have resulted in more high energy tracks which could be measured.

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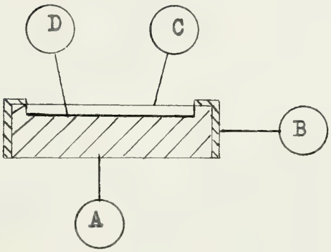

(A) Brass mount.

(B) Brass sleeve.

(C) Aluminum window.

(D) Radioactive material.

(Plate 16)

Standard Sources.

Appendix 1.

Preparation of Standard Sources (Plate 16)

The counting rate as recorded on a given Geiger tube apparatus deviates from day to day to an extent which is greater than is to be expected from statistical considerations alone. Thus, to compare readings made over an extended period of time, it is necessary to normalize the data collected against the count from a standard source. Suitably designed standard sources should have certain attributes:

(1) Construction preventing any loss in radioactivity through normal handling.

(2) A long half-period to provide a constant source of radiation.

(3) Radiation identical in kind and similar in energy to that being studied.

Powdered uranium nitrate* was used in this work as the radioactive material. A thin layer of the source material was spread uniformly on each brass mount. The activities were adjusted as in the following table by varying the amount of uranium nitrate used.

Standard Source	cpm. Shelf No. 1	cpm. Shelf No. 2	cpm. Shelf No. 3
1	11400	4300	2000
2	6000	2300	1100
3	5500	1900	1000
4	4300	1600	800
5	2100	750	350

* End-point energy of the beta spectrum of UXI is 2.32 mev.

The material was covered with a thin coat of lucite dissolved in hot amyl acetate. This cemented the uranium nitrate and assured a constant geometry. A snugly fitting brass sleeve with one end covered with an aluminum window 0.0023" thick (16 mg/cm^2) was placed over the brass mount and cemented with Duco Household Cement. The complete standard source was then coated with a thin coat of the dissolved lucite and allowed to dry.

Appendix 2.

Calculation of Errors in the Higher Energies for the Fermi Distribution

From Introduction on Fermi's theory of beta disintegration,

$$F(E) = \left(\frac{N(E)}{E(E^2 - 1)^{1/2}} \right)^{1/2}$$

$$\ln F = 1/2 \ln N - 1/2 \ln E - 1/4 \ln (E^2 - 1)$$

$$\frac{dF}{F} = \frac{dN}{2N} - \frac{dE}{2E} - \frac{EdE}{2(E^2 - 1)}$$

For the maximum error,

$$dF = \frac{FdN}{2N} + \frac{FdE}{2} \left(\frac{1}{E} + \frac{E}{E^2 - 1} \right) \quad \text{.....................(5)}$$

The error in E was calculated by setting limits on the accuracy of measuring the sagitta length for a track of energy E. The error in N for any interval was then found by calculating the error in the $H\rho$ limits for that interval and counting the number of tracks that fell within this error. The error in F was calculated using equation (5). These errors for the higher energies were plotted on graph (6).

Appendix 3

Calculation of the Source Activity

Rubidium occurs in the periodic table in the same series as lithium, sodium, potassium, and caesium and hence is a very strong reducing agent. It was necessary therefore to choose a rubidium compound; also one whose constituents after irradiation would not interfere with the measurements to be taken on Rb^{86}. For this reason, Rb_2CO_3 was chosen as the compound to be irradiated. Neutron bombardment of carbon and oxygen results in activities with half-lives of the order of seconds and minutes and these activities would be negligibly small after a lapse of ten days. Rubidium consists of two natural isotopes, ${}_{37}Rb^{85}$ (72.8%) and ${}_{37}Rb^{87}$ (27.2%). Neutron bombardment results in the following activities:

			Half life
${}_{37}Rb^{85}$ (n, 2n)	${}_{37}Rb^{84}$	β^+	34 days
${}_{37}Rb^{85}$ (n, γ)	${}_{37}Rb^{86}$	β^-	19.5 days
${}_{37}Rb^{85}$ (n, p)	${}_{36}Kr^{85}$	β^-	4 hours
${}_{37}Rb^{87}$ (n, α)	${}_{35}Rb^{84}$	β^-	30 min.
${}_{37}Rb^{87}$ (n, γ)	${}_{37}Rb^{88}$	β^-	17.5 min.

The last three activities would also be negligibly small after a lapse of ten days. The (n, 2n) reaction requires high energy neutrons and the probability for such a reaction in the Chalk River pile is very low. The following calculation, therefore, gives the activity due to Rb^{86} alone, all others being neglected.

Weight of Rb_2CO_3 = 5 mg.

Weight of ${}_{37}Rb^{85}$ = 2.71 mg.

No. of atoms of ${}_{37}Rb^{85} = \dfrac{6.02 \times 10^{23}}{85} \times 2.71 \times 10^{-3}$

$= 19.2 \times 10^{18}$ atoms.

Substituting in the formula,

$$A = \sigma N Q(1 - e^{-\lambda t})$$

where N= number of atoms of the material present.

Q = neutron flux density = 10^{13} neutrons per cm^2 per sec.

σ = cross section for the desired reaction = 0.72 barns

λ = decay constant of product

t = irradiation time = 1 day

A = resulting activity of product after irradiation,

we obtain,

$$A = 0.72 \times 10^{-24} \times 19.2 \times 10^{18} \times 10^{13} \left(1 - e^{-\frac{0.693}{19.5}}\right) \frac{\text{dis.}}{\text{sec.}}$$

$= 0.47 \times 10^{7}$ dis/sec = 0.13 mc.